



OFFICE OF  
THE CHAIRMAN

FEDERAL COMMUNICATIONS COMMISSION  
WASHINGTON

June 12, 2020

The Honorable Chris Coons  
United States Senate  
127A Russell Senate Office Building  
Washington, DC 20510

Dear Senator Coons:

Thank you for your letter regarding the Commission's unanimous, bipartisan decision to approve with stringent conditions Ligado's application to deploy a low-power terrestrial network in L-band spectrum. I greatly appreciate your support for spectrum policies driven by data and sound engineering as we seek to maintain our nation's leadership in 5G, the next generation of wireless connectivity.

Accordingly, I appreciate the opportunity to answer your questions and clear up some misinformation that has been disseminated regarding the Commission's Ligado decision. Here are my responses to your specific questions.

*How long was the Ligado proceeding on the Commission's docket?*

The Ligado proceeding has been pending for nine years, dating back to the January 2011 authorization to allow Ligado's predecessor-in-interest to commence terrestrial operations if the Commission concluded (after consultation with the Department of Commerce's National Telecommunications and Information Administration) that harmful interference concerns relating to GPS devices had been resolved. (Note: I became a member of the Commission over one year later, in May 2012.)

This proceeding is linked to the Commission's 2003 rulemaking and 2004 authorization to allow terrestrial operations, known as the "ancillary terrestrial component," in this spectrum, which is the 1525-1559 MHz band. This decision was coordinated with the NTIA and used strict emissions limits to create a "quiet zone" to protect from harmful interference GPS operations within the adjacent 1559-1610 band, which is allocated to Radionavigation-Satellite Service (RNSS). In 2005, Commission affirmed its decision to allow terrestrial operations in 1525-1559 MHz band and modified the technical rules to address federal and industry GPS stakeholder concerns.

*Please describe the FCC's evaluation of the Ligado application and why the FCC believes granting this application is in the public interest?*

The Commission has an obligation to review all potential spectrum uses in the public interest. It is a core mission mandated by Congress in law. Recognizing that part of this mission involves promoting American leadership and innovation in 5G, we have created a comprehensive strategy to Facilitate America's Superiority in 5G Technology—the 5G FAST Plan. The plan emphasizes the importance of making more spectrum available for commercial

use. Accordingly, our staff is constantly working to find more ways to maximize efficient use of spectrum for commercial use.

Our decision with respect to the L-band fulfills this goal. Specifically, we found that Ligado's modified application could support 5G and Internet of Things services through an innovative approach to make more efficient use of underused spectrum in the 1525-1536 MHz portion of the mobile satellite band while protecting GPS users in the nearby 1559-1610 MHz radionavigation satellite band.

*The Federal Aviation Administration (FAA) made recommendations to the Commission to protect certified aviation devices from harmful interference. Did the Commission adopt these recommendations?*

Yes, we followed the recommendations of the FAA and the Department of Transportation for certified aviation receivers. See, for example, paragraph 61 of the FCC's Ligado Order ("For certified aviation GPS receivers, we rely on the performance-based standard and analyses conducted by the FAA and presented in the 2018 DOT ABC Report."); see also paragraph 71 ("We accept the FAA's standards-based analyses relating to certified aviation devices and condition Ligado's ATC operations accordingly. The FAA is the expert agency with a critical interest in ensuring the reliability of certified aviation GPS devices.").

*Reports indicate that Ligado entered into co-existence agreements with the major GPS equipment manufacturers. Could you provide a list of which GPS manufacturers that entered into such agreements?*

Since 2015, Ligado has entered into agreements with six different GPS device manufacturers: (1) Garmin International, Inc.; (2) Deere & Company; (3) Trimble Navigation Limited; (4) NovAtel Inc.; (5) Topcon Positioning Systems, Inc.; and (6) Hexagon Positioning Intelligence.

*Roughly what percentage of the GPS market is represented by the manufacturers with these co-existence agreements?*

Based on the record, we expect these manufacturers represent a significant majority of the GPS market. For example, a Brattle Group study indicates that these are the largest manufacturers in four categories of GPS devices—general location/navigation (Garmin), high-precision (Trimble, Deere, Topcon, and Leica), timing (Trimble), and certified aviation (Garmin)—with Garmin alone accounting for nearly half of all consumer general location/navigation device sales in 2015.

*The Commission's order required Ligado to operate its base stations at a 99.3% reduced power level from its original proposal. Why did the Commission conclude that this reduced power level will allow Ligado to operate a terrestrial network that can co-exist with operations in adjacent spectrum bands?*

The power levels were established based on the FAA's analysis relating to protection of certified aviation receivers. To be sure, Ligado's agreements with several GPS device manufacturers indicated that the company's operations even at the higher levels could co-exist with GPS operations. But significantly reducing the permitted power levels goes even further in ensuring that Ligado's lower power operations can co-exist with GPS operations without causing harmful interference.

Furthermore, the Commission also established stringent conditions, including notification requirements, to promote this co-existence. Additional conditions were established specifically to protect U.S. Government users, including the expectation that Ligado and U.S. Government users would negotiate lower power levels (and possible limited exclusion zones), if necessary, to protect sensitive military systems. We also note that the approved power levels also are more than 99% lower than the power levels initially authorized by the Commission for the band in 2004.

*The Commission required Ligado to use a 23 MHz guard band consisting of Ligado's own spectrum. Why does the Commission believe that this guard band will protect from harmful interference?*

The establishment of a 23 megahertz guard band to protect GPS operations effectively extends the quiet zone beyond the 1559-1610 MHz RNSS allocation where GPS satellites operate and into Ligado's own licensed spectrum. That is, Ligado is required effectively to forfeit the use of 23 megahertz of its own spectrum for commercial operations in order to create a buffer between its operations and GPS. (By contrast, the guard band the Commission established in the 600 MHz band between full-power wireless operations and Channel 37 following the broadcast incentive auction was only 3 megahertz, from 614-617 MHz—less than one-seventh as large.) The extended quiet zone is particularly helpful to resolving potential harmful interference to high-precision receivers that are designed to receive signals outside of the RNSS allocation. Testing data in the FCC's record shows that some high-precision receivers operate with mobile satellite service satellites and with GPS satellites simultaneously and others have antennas that, by their design, capture energy outside of the RNSS allocation through use of spectrally inefficient antennas. Colloquially speaking, they "bleed over" into Ligado's spectrum. The guard-band provides an additional quiet zone for these types of high-precision receivers—again, taken out of Ligado's own licensed spectrum.

*Opponents of the FCC's decision have suggested that the guardband is insufficient because GPS receivers are designed to tolerate interference from space systems in adjacent spectrum, but not interference from terrestrial systems in that spectrum. Did the Commission consider and address this concern? If so, how?*

Yes, we considered and addressed this concern. Recall that the Commission, following coordination with NTIA, established rules to permit licensees such as Ligado to operate ancillary terrestrial-based services in 2003, including in the spectrum adjacent to the RNSS allocation. Recall also that in 2004, a predecessor-in-interest to Ligado was authorized to deploy terrestrial operations in that band (the 1525-1559 MHz band) at power levels significantly higher than those we just authorized in the *Ligado Order*. The GPS industry and users knew of the Commission's rulemaking decisions and authorization—and participated in the rulemaking and authorization processes—and the items were appropriately coordinated with NTIA on behalf of federal agencies. In 2005, the Commission affirmed its decision to permit ancillary terrestrial-based operations and addressed all petitions to reconsider the Commission's 2003 decision.

Even though the technical and operational parameters were established and well known by all parties a decade and a half ago, the Commission nonetheless fully examined the data and technical analysis in the record of this recent proceeding. It found that that GPS receivers of all types—including high-precision receivers—are capable of operating effectively with the 23-megahertz guard band inside the 1525-1559 MHz band. In general, the record showed that the



vast majority of GPS receivers would not receive any harmful interference. The Roberson Study found that some of the high-precision receivers, which were most susceptible to interference, were potentially vulnerable, but that repair or replacement of filters would enable the devices to operate without adverse performance impacts. The National Advanced Spectrum and Communications Test Network (NASCTN) report provided support for that same finding. It also found that replacing the antennas of the most vulnerable high-precision devices with a spectrally efficient antenna showed significant susceptibility improvements. Accordingly, the Commission conditioned its approval on Ligado taking responsibility for upgrading or replacing federal agency high-precision receivers, given that interference concerns could be resolved by repairing the receiver or replacing it with receivers with better-performing filters that are designed to operate well primarily within the RNSS allocation (the 1559-1610 MHz band). That is to say, the new receivers are designed to ensure that GPS receivers will not “bleed over” into Ligado’s spectrum. Along with the condition establishing a 23 megahertz guard band, this condition provides significant protection for high-precision receivers using spectrally efficient antennas and enables them to coexist with Ligado’s terrestrial, low-power network.

*What is the National Advanced Spectrum and Communications Test Network (NASCTN)?*

NASCTN is a multi-agency-chartered partnership that seeks to provide a “neutral forum” for testing, modeling, and analysis necessary to inform spectrum policy and regulations. NASCTN was created in 2015 and is a joint effort involving the National Institute of Standards and Technology, NTIA, DOD, the National Aeronautical and Space Administration, the National Science Foundation, and the National Oceanic and Atmospheric Administration. According to its charter, the organization’s purpose is to “improve opportunities for successful spectrum sharing through accurate, reliable, and unbiased measurements and analyses.”

*During the SASC hearing, critics of the decision suggested that the selection of NASCTN to conduct a study on interference was made by Ligado and therefore produced biased results in favor of Ligado’s position. How does the Commission respond to this assertion?*

There is no evidence that NASCTN produced biased results in favor of Ligado’s position. Indeed, as detailed above, NASCTN includes the participation of certain entities, such as the Department of Defense, which have not been shy about expressing their opposition to the merits of the FCC’s decision. Ligado commissioned NASCTN in April 2016 to study the impact of long-term evolution (LTE) signals in Ligado’s spectrum on GPS devices that operate in the nearby band. The NASCTN tested 14 devices in different categories, including general location/navigation receivers, high-precision (including real-time kinematic) receivers, and GPS-disciplined oscillator (i.e., timing) receivers, and also tested several different antennas—all with resulting details and descriptions designed to facilitate rigorous review and replication of testing of each device under test configured for typical use. The Commission found the data and technical analysis in the NASCTN report to be informative and helpful in assessing the interference concerns at issue.

*Is 1db a standard metric that the Commission has used previously for determinations of harmful interference to adjacent bands?*

No. The Commission has never before applied this metric for determinations of harmful interference to adjacent bands. Similarly, the International Telecommunications Union has not recommended that a 1 dB interference protection criterion be used to set emissions levels to protect against harmful interference in adjacent bands.



*Why was 1db not adopted by the Commission in this instance?*

In paragraph 49 of the *Ligado Order*, the Commission relied on its long-standing definition of “harmful interference”: “[i]nterference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with [international] Radio Regulations.” Notably, this is the same definition used by NTIA and the International Telecommunications Union.

The Commission declined to adopt the 1 dB  $C/N_0$  metric because the record demonstrated that it was poor indicator of harmful interference. *First*, data in the record indicated that a 1 dB  $C/N_0$  degradation does not correlate to any significant error in a GPS device’s reporting of position. In other words, a 1dB  $C/N_0$  degradation does not correlate with harmful interference. *Second*, the model used to apply the metric is not reliable. Studies in the record showed that the variability (error) in reported  $C/N_0$  can be significant, as much as 2-3 dB, due to technical variances in the  $C/N_0$  estimators incorporated in GPS receivers and the algorithms used to calculate  $C/N_0$ . That is, the error in measuring the change in performance can be significantly more than the metric itself that one is trying to apply! For some implementations, the data showed that the  $C/N_0$  estimator provided erroneous  $C/N_0$  estimates more frequently than it provided accurate ones. Indeed, the Commission found that the data “strongly suggest that the  $C/N_0$  estimators are generally not capable of accurate and reliable detection of a 1 dB change in the noise power component of the  $C/N_0$ .” *Finally*, on top of all this, variations in this metric occur even without a signal from Ligado—for example, a GPS receiver may experience a 1 dB or 2 dB degradation through natural occurrences.

In sum, the only reason to use a proxy for harmful interference, like the 1 dB  $C/N_0$  metric, is if it can accurately predict harmful interference more quickly than performance-based testing. That is not the case here. The record amply demonstrated that the 1 dB metric repeatedly failed to accurately predict harmful interference, and on top of that, the Commission had access to actual and credible performance-based testing—testing that it relied upon to ensure there would not be harmful interference.

*If 1db is not the Commission’s standard, how would the use of a 1db standard as proposed by some affect current wireless communications?*

Adoption of such a standard for adjacent band operations could have a profound, negative impact on wireless communications. For example, applying the 1dB  $C/N_0$  metric would have required the Commission to reduce Ligado’s authorized base station power by another 99.99898%, down to 1/1,000 of a watt, less than the power of a Bluetooth device. And applying that metric to Ligado’s authorized power levels would predict harmful interference to GPS receivers on cellphones, despite extensive testing in 2011 (that NTIA acknowledged in 2012) showing no such harmful interference from deployments with 16,073% higher power (1,585 Watts) than the 9.8 Watts approved in the *Ligado Order*.

Applied more broadly, use of this metric would undermine the Commission’s ability to promote efficient use of spectrum and effectively prohibit wireless communications as they stand today in many bands. It would impede, if not implode, the Commission’s ability to reallocate new spectrum to 5G and other next-generation services. It would reduce incentives for incumbents to design spectrally efficient receivers. And from the perspective of millions of

American wireless consumers, this metric would be devastating, forestalling the introduction of advanced wireless services and disincentivizing the development of new wireless devices.

*Did the FCC give other federal agencies notice of the final order prior to its release on April 16, 2020?*

Yes. Federal agencies had actual possession of the draft that the FCC was poised to adopt—and thus an opportunity to comment on it—for almost *half a year* before the FCC finally adopted it.

*If so, which agencies, when where they given notice, and what specific opportunities for input were they afforded prior to the issuance of the final order?*

In October 2019, the FCC sent a draft to NTIA for coordination with the Interdepartment Radio Advisory Committee (IRAC). Led by NTIA, the IRAC's members include the Department of Defense (the Air Force, the Army, the Coast Guard, and the Navy), the Department of Agriculture, the Department of Commerce, the Department of Energy, the Federal Aviation Administration, the Department of Homeland Security, the Department of the Interior, the Department of Justice, the National Aeronautics and Space Administration, the National Science Foundation, the Department of State, the Department of Transportation, the Department of the Treasury, the United States Agency for Global Media, the United States Postal Service, and the Department of Veterans Affairs. In the typical situation, the IRAC process provides for a three-week period for feedback. But in order to give federal agencies more time to formulate comments on the FCC's draft decision, the Commission agreed to extend that three-week period for an additional month.

After receiving input from federal agencies in December 2019, when the Department of Defense informed the Commission that it had additional information to submit for the public record, the FCC paused further work on the application until March so that the Department would have yet another opportunity to share its views with the Commission. Although NTIA did supply additional information from the Department of Defense in April 2020 (a February 2020 Air Force memorandum), it did not supply any additional technical analysis for the Commission's consideration.

*What other dialogue or discussions did you maintain with federal agencies throughout this process?*

In addition to staff discussions, I personally spoke with Secretary of Defense Mark Esper, Under Secretary of Defense for Research and Engineering Michael Griffin, and Deputy Under Secretary of Defense for Research and Engineering Lisa Porter about the matter. I am informed that Commission staff as well were in frequent contact with their counterparts at the Department. In short, federal agencies had every possible opportunity to make their cases to the Commission.

*In December 2019, the NTIA sent the FCC a letter that explained it was "unable to recommend the Commission's approval of the Ligado applications." Please describe NTIA's concerns and what steps, if any, the FCC took to address them? Which concerns did the FCC disagree with and why?*

NTIA's December 2019 letter did not itself raise any concerns with the Commission's approval of the Ligado applications, nor did it identify any technical errors in the draft order that the Commission provided to NTIA for the Interdepartment Radio Advisory Committee process. Instead, it lauded the federal government's "tremendous success in making available spectrum



that can support 5G,” argued that GPS is “fundamental to the Nation’s economy, national security, and continued technological leadership,” and noted that “federal agencies have significant concerns,” attaching a December 2018 letter from the National Executive Committee for Space-Based Positioning, Navigation, and Timing (PNT EXCOM), a June 2019 letter from the Department of Defense, and a November 2019 letter from the Department. As detailed in the *Ligado Order*, the Commission appreciated NTIA’s recognition of its work on 5G, agreed on the importance of GPS, and responded to the letters from federal agencies at length.

But neither NTIA’s December 6, 2019 letter, the PNT EXCOM’s December 2018 letter, the Department of Defense’s June 2019 letter, nor the Department of Defense’s November 2019 letter conveyed any new information, data, or arguments not already in the record before the Commission. These submissions simply did not address the substance or technical merits of the approach that the FCC proposed to use to assess the potential for harmful interference to GPS.

Instead, the letters from PNT EXCOM and DOD recommended that any operations in bands adjacent to GPS should not be approved unless, at a minimum, they do not exceed the “tolerable power transmission limits” described in the Department of Transportation’s April 2018 Global Positioning System (GPS) Adjacent Band Compatibility Assessment Final Report. That report, in turn, based its analysis on the flawed 1 dB metric that, as described above, the Commission found to be a poor indicator of harmful interference.

As a result, the Commission did not find these letters persuasive. Instead, following a thorough evaluation of the technical assessments in the record, including those cited by federal agencies in their letters, the Commission concluded that approval of Ligado’s modified applications, with the stringent conditions that we imposed, addressed and resolved the potential harmful interference concerns relating to Ligado’s proposed operations (both generally and specifically with respect to federal users) and would promote the efficient use of spectrum in the public interest.

I would note that in April 2020, NTIA submitted an Air Force memorandum that contained no new technical data for the Commission’s consideration but questioned Ligado’s ability to repair or replace potentially affected legacy equipment. To address this concern, the Commission included additional obligations for Ligado to work with the Department of Defense on mutually agreeable lower power levels over affected military installations and possible exclusion zones.

*The Commission required Ligado to have an “emergency shut off switch” after a notification of credible interference. When would Ligado be required to shut off its network?*

In the *Ligado Order*, the Commission adopted requirements and procedures to ensure the immediate suspension of operations that could potentially cause harmful interference to other services. This “stop buzzer” capability is designed to address an unforeseen disruption to GPS. Ligado must be able to cease transmissions of all base station transmitters within the radio horizon of the impacted area *within 15 minutes* of receiving a request from the FCC’s Operations Center. Any federal agency, Ligado itself, or another source may notify the FCC’s Operations Center of such a GPS disruption.

*Has the Commission previously required an “emergency shut off switch” on spectrum license holders?*



Although this is analogous to a condition the Commission places on experimental licensees, which operate on a non-interference basis relative to other licensees, the Commission has never before required a non-experimental licensee to operate pursuant to this type of requirement. This condition was specifically crafted in the *Ligado Order* to address the concerns of federal users.

*What notification requirements did the Commission place on Ligado prior to base station activations?*

Ligado is subject to several comprehensive conditions designed to help protect GPS users from any potential harmful interference. While some may argue that these conditions go beyond what is necessary given the evidence in the record, I thought that it was important for the Commission to go the extra mile to ensure that military and civilian operations are protected. Specifically, Ligado is subject to the following conditions:

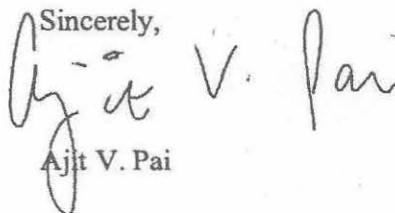
- *Coordination with GPS Device Manufacturers:* Ligado must provide no less than six months' advance notice regarding the activation of any base station transmitting in the 1526-1536 MHz band to Garmin, Deere, Trimble, NovAtel, Topcon, Hexagon, Septentrio, and Leica as well as any other GPS manufacturing company that Ligado knows or reasonably should know could potentially be affected by Ligado's terrestrial network operations.
- *Coordination with Aviation Community:* Ligado must establish a database available to the aviation community and include the base station information at least 30 days before commencing transmission at a base station site. The database must include, at a minimum: (1) location of the proposed base station antenna site (latitude and longitude); (2) base station antenna radiation center height above ground level; (3) base station antenna tilt for both mechanical and electrical tilt; and (4) base station antenna specification, including polarization and pattern. Ligado must also update the database to enter the required base station technical parameters for any subsequently activated base station at least 30 days prior to commencing any transmission.
- *Coordination with Federal GPS Users:* Ligado must launch a program to facilitate the exchange of information between itself and the U.S. Government. Specifically, Ligado must cooperate directly with any U.S. government agency that anticipates that its GPS devices may be affected by Ligado's terrestrial operations by: (1) providing base station location information and technical operating parameters to federal agencies prior to commencing operations in the 1526-1536 MHz band; (2) working with the affected agency to identify the devices that could be affected; (3) working with the affected agency to evaluate whether there would be harmful interference from Ligado's operations; and (4) developing a program for device repair or replacement that is consistent with that agency's programmatic needs, as well as applicable statutes and regulations relating to the ability of those agencies to accept this type of support. Moreover, in the event an affected government agency determines that Ligado's operations will cause harmful interference to a specific, identified GPS receiver operating on a military installation and the receiver is incapable of being fully tested or replaced, Ligado and the affected agency must negotiate an acceptable received-power level over the military installation (which may result in an exclusion zone over the military installation).

- *FCC and FAA Downlink Operations Reports:* At least 30 days before commencing transmission at a base station site, Ligado must submit to the FCC and the FAA a report that includes, at a minimum: (1) location of the proposed base station antenna site (latitude and longitude); (2) base station antenna radiation center height above ground level; (3) base station antenna tilt for both mechanical and electrical tilt; and (4) base station antenna specification, including polarization and pattern.
- *Drive-Test Requirements.* Ligado must conduct drive testing to assess actual transmit power levels in the 1526-1536 MHz band to further ensure that its deployed transmit power levels are consistent with the conditions and coordination requirements (e.g., providing coverage maps and monitoring base station transmit power) with GPS device manufacturers. Also, no later than six months following initial base deployments, Ligado must conduct a drive test for each of its deployed areas, and do so for each of its subsequently deployed areas every six months.
- *Public Reporting Mechanism:* Ligado must establish and maintain a toll-free telephone number for the public to report apparent incidences of interference from Ligado's operations to GPS operations.

\* \* \*

Thank you for this opportunity to answer your questions related to the Commission's unanimous, bipartisan decision to continue promoting American leadership in 5G and to protect the important services enabled by GPS. If you would like to discuss this matter further, the FCC stands ready to brief you and your staff on our work.

Sincerely,

A handwritten signature in dark ink, appearing to read "Ajit V. Pai". The signature is fluid and cursive, with the first name "Ajit" being the most prominent part.

Ajit V. Pai



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NASCTN is a multi-agency-chartered partnership that seeks to provide a “neutral forum” for testing, modeling, and analysis necessary to inform spectrum policy and regulations. NASCTN was created in 2015 and is a joint effort involving the National Institute of Standards and Technology, NTIA, DOD, the National Aeronautical and Space Administration, the National Science Foundation, and the National Oceanic and Atmospheric Administration. According to its charter, the organization’s purpose is to “improve opportunities for successful spectrum sharing through accurate, reliable, and unbiased measurements and analyses.”

*During the SASC hearing, critics of the decision suggested that the selection of NASCTN to conduct a study on interference was made by Ligado and therefore produced biased results in favor of Ligado’s position. How does the Commission respond to this assertion?*

There is no evidence that NASCTN produced biased results in favor of Ligado’s position. Indeed, as detailed above, NASCTN includes the participation of certain entities, such as the Department of Defense, which have not been shy about expressing their opposition to the merits of the FCC’s decision. Ligado commissioned NASCTN in April 2016 to study the impact of long-term evolution (LTE) signals in Ligado’s spectrum on GPS devices that operate in the nearby band. The NASCTN tested 14 devices in different categories, including general location/navigation receivers, high-precision (including real-time kinematic) receivers, and GPS-disciplined oscillator (i.e., timing) receivers, and also tested several different antennas—all with resulting details and descriptions designed to facilitate rigorous review and replication of testing of each device under test configured for typical use. The Commission found the data and technical analysis in the NASCTN report to be informative and helpful in assessing the interference concerns at issue.

*Is 1db a standard metric that the Commission has used previously for determinations of harmful interference to adjacent bands?*

No. The Commission has never before applied this metric for determinations of harmful interference to adjacent bands. Similarly, the International Telecommunications Union has not recommended that a 1 dB interference protection criterion be used to set emissions levels to protect against harmful interference in adjacent bands.



*Why was 1db not adopted by the Commission in this instance?*

In paragraph 49 of the *Ligado Order*, the Commission relied on its long-standing definition of “harmful interference”: “[i]nterference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with [international] Radio Regulations.” Notably, this is the same definition used by NTIA and the International Telecommunications Union.

The Commission declined to adopt the 1 dB  $C/N_0$  metric because the record demonstrated that it was poor indicator of harmful interference. *First*, data in the record indicated that a 1 dB  $C/N_0$  degradation does not correlate to any significant error in a GPS device’s reporting of position. In other words, a 1dB  $C/N_0$  degradation does not correlate with harmful interference. *Second*, the model used to apply the metric is not reliable. Studies in the record showed that the variability (error) in reported  $C/N_0$  can be significant, as much as 2-3 dB, due to technical variances in the  $C/N_0$  estimators incorporated in GPS receivers and the algorithms used to calculate  $C/N_0$ . That is, the error in measuring the change in performance can be significantly more than the metric itself that one is trying to apply! For some implementations, the data showed that the  $C/N_0$  estimator provided erroneous  $C/N_0$  estimates more frequently than it provided accurate ones. Indeed, the Commission found that the data “strongly suggest that the  $C/N_0$  estimators are generally not capable of accurate and reliable detection of a 1 dB change in the noise power component of the  $C/N_0$ .” *Finally*, on top of all this, variations in this metric occur even without a signal from Ligado—for example, a GPS receiver may experience a 1 dB or 2 dB degradation through natural occurrences.

In sum, the only reason to use a proxy for harmful interference, like the 1 dB  $C/N_0$  metric, is if it can accurately predict harmful interference more quickly than performance-based testing. That is not the case here. The record amply demonstrated that the 1 dB metric repeatedly failed to accurately predict harmful interference, and on top of that, the Commission had access to actual and credible performance-based testing—testing that it relied upon to ensure there would not be harmful interference.

*If 1db is not the Commission’s standard, how would the use of a 1db standard as proposed by some affect current wireless communications?*

Adoption of such a standard for adjacent band operations could have a profound, negative impact on wireless communications. For example, applying the 1dB  $C/N_0$  metric would have required the Commission to reduce Ligado’s authorized base station power by another 99.99898%, down to 1/1,000 of a watt, less than the power of a Bluetooth device. And applying that metric to Ligado’s authorized power levels would predict harmful interference to GPS receivers on cellphones, despite extensive testing in 2011 (that NTIA acknowledged in 2012) showing no such harmful interference from deployments with 16,073% higher power (1,585 Watts) than the 9.8 Watts approved in the *Ligado Order*.

Applied more broadly, use of this metric would undermine the Commission’s ability to promote efficient use of spectrum and effectively prohibit wireless communications as they stand today in many bands. It would impede, if not implode, the Commission’s ability to reallocate new spectrum to 5G and other next-generation services. It would reduce incentives for incumbents to design spectrally efficient receivers. And from the perspective of millions of

American wireless consumers, this metric would be devastating, forestalling the introduction of advanced wireless services and disincentivizing the development of new wireless devices.

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*If so, which agencies, when where they given notice, and what specific opportunities for input were they afforded prior to the issuance of the final order?*

In October 2019, the FCC sent a draft to NTIA for coordination with the Interdepartment Radio Advisory Committee (IRAC). Led by NTIA, the IRAC's members include the Department of Defense (the Air Force, the Army, the Coast Guard, and the Navy), the Department of Agriculture, the Department of Commerce, the Department of Energy, the Federal Aviation Administration, the Department of Homeland Security, the Department of the Interior, the Department of Justice, the National Aeronautics and Space Administration, the National Science Foundation, the Department of State, the Department of Transportation, the Department of the Treasury, the United States Agency for Global Media, the United States Postal Service, and the Department of Veterans Affairs. In the typical situation, the IRAC process provides for a three-week period for feedback. But in order to give federal agencies more time to formulate comments on the FCC's draft decision, the Commission agreed to extend that three-week period for an additional month.

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*What other dialogue or discussions did you maintain with federal agencies throughout this process?*

In addition to staff discussions, I personally spoke with Secretary of Defense Mark Esper, Under Secretary of Defense for Research and Engineering Michael Griffin, and Deputy Under Secretary of Defense for Research and Engineering Lisa Porter about the matter. I am informed that Commission staff as well were in frequent contact with their counterparts at the Department. In short, federal agencies had every possible opportunity to make their cases to the Commission.

*In December 2019, the NTIA sent the FCC a letter that explained it was "unable to recommend the Commission's approval of the Ligado applications." Please describe NTIA's concerns and what steps, if any, the FCC took to address them? Which concerns did the FCC disagree with and why?*

NTIA's December 2019 letter did not itself raise any concerns with the Commission's approval of the Ligado applications, nor did it identify any technical errors in the draft order that the Commission provided to NTIA for the Interdepartment Radio Advisory Committee process. Instead, it lauded the federal government's "tremendous success in making available spectrum

that can support 5G,” argued that GPS is “fundamental to the Nation’s economy, national security, and continued technological leadership,” and noted that “federal agencies have significant concerns,” attaching a December 2018 letter from the National Executive Committee for Space-Based Positioning, Navigation, and Timing (PNT EXCOM), a June 2019 letter from the Department of Defense, and a November 2019 letter from the Department. As detailed in the *Ligado Order*, the Commission appreciated NTIA’s recognition of its work on 5G, agreed on the importance of GPS, and responded to the letters from federal agencies at length.

But neither NTIA’s December 6, 2019 letter, the PNT EXCOM’s December 2018 letter, the Department of Defense’s June 2019 letter, nor the Department of Defense’s November 2019 letter conveyed any new information, data, or arguments not already in the record before the Commission. These submissions simply did not address the substance or technical merits of the approach that the FCC proposed to use to assess the potential for harmful interference to GPS.

Instead, the letters from PNT EXCOM and DOD recommended that any operations in bands adjacent to GPS should not be approved unless, at a minimum, they do not exceed the “tolerable power transmission limits” described in the Department of Transportation’s April 2018 Global Positioning System (GPS) Adjacent Band Compatibility Assessment Final Report. That report, in turn, based its analysis on the flawed 1 dB metric that, as described above, the Commission found to be a poor indicator of harmful interference.

As a result, the Commission did not find these letters persuasive. Instead, following a thorough evaluation of the technical assessments in the record, including those cited by federal agencies in their letters, the Commission concluded that approval of Ligado’s modified applications, with the stringent conditions that we imposed, addressed and resolved the potential harmful interference concerns relating to Ligado’s proposed operations (both generally and specifically with respect to federal users) and would promote the efficient use of spectrum in the public interest.

I would note that in April 2020, NTIA submitted an Air Force memorandum that contained no new technical data for the Commission’s consideration but questioned Ligado’s ability to repair or replace potentially affected legacy equipment. To address this concern, the Commission included additional obligations for Ligado to work with the Department of Defense on mutually agreeable lower power levels over affected military installations and possible exclusion zones.

*The Commission required Ligado to have an “emergency shut off switch” after a notification of credible interference. When would Ligado be required to shut off its network?*

In the *Ligado Order*, the Commission adopted requirements and procedures to ensure the immediate suspension of operations that could potentially cause harmful interference to other services. This “stop buzzer” capability is designed to address an unforeseen disruption to GPS. Ligado must be able to cease transmissions of all base station transmitters within the radio horizon of the impacted area *within 15 minutes* of receiving a request from the FCC’s Operations Center. Any federal agency, Ligado itself, or another source may notify the FCC’s Operations Center of such a GPS disruption.

*Has the Commission previously required an “emergency shut off switch” on spectrum license holders?*



Although this is analogous to a condition the Commission places on experimental licensees, which operate on a non-interference basis relative to other licensees, the Commission has never before required a non-experimental licensee to operate pursuant to this type of requirement. This condition was specifically crafted in the *Ligado Order* to address the concerns of federal users.

*What notification requirements did the Commission place on Ligado prior to base station activations?*

Ligado is subject to several comprehensive conditions designed to help protect GPS users from any potential harmful interference. While some may argue that these conditions go beyond what is necessary given the evidence in the record, I thought that it was important for the Commission to go the extra mile to ensure that military and civilian operations are protected. Specifically, Ligado is subject to the following conditions:

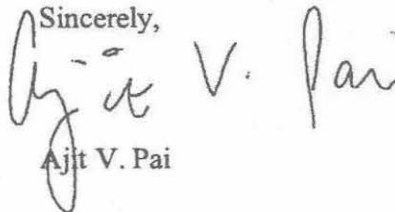
- *Coordination with GPS Device Manufacturers:* Ligado must provide no less than six months' advance notice regarding the activation of any base station transmitting in the 1526-1536 MHz band to Garmin, Deere, Trimble, NovAtel, Topcon, Hexagon, Septentrio, and Leica as well as any other GPS manufacturing company that Ligado knows or reasonably should know could potentially be affected by Ligado's terrestrial network operations.
- *Coordination with Aviation Community:* Ligado must establish a database available to the aviation community and include the base station information at least 30 days before commencing transmission at a base station site. The database must include, at a minimum: (1) location of the proposed base station antenna site (latitude and longitude); (2) base station antenna radiation center height above ground level; (3) base station antenna tilt for both mechanical and electrical tilt; and (4) base station antenna specification, including polarization and pattern. Ligado must also update the database to enter the required base station technical parameters for any subsequently activated base station at least 30 days prior to commencing any transmission.
- *Coordination with Federal GPS Users:* Ligado must launch a program to facilitate the exchange of information between itself and the U.S. Government. Specifically, Ligado must cooperate directly with any U.S. government agency that anticipates that its GPS devices may be affected by Ligado's terrestrial operations by: (1) providing base station location information and technical operating parameters to federal agencies prior to commencing operations in the 1526-1536 MHz band; (2) working with the affected agency to identify the devices that could be affected; (3) working with the affected agency to evaluate whether there would be harmful interference from Ligado's operations; and (4) developing a program for device repair or replacement that is consistent with that agency's programmatic needs, as well as applicable statutes and regulations relating to the ability of those agencies to accept this type of support. Moreover, in the event an affected government agency determines that Ligado's operations will cause harmful interference to a specific, identified GPS receiver operating on a military installation and the receiver is incapable of being fully tested or replaced, Ligado and the affected agency must negotiate an acceptable received-power level over the military installation (which may result in an exclusion zone over the military installation).

- *FCC and FAA Downlink Operations Reports:* At least 30 days before commencing transmission at a base station site, Ligado must submit to the FCC and the FAA a report that includes, at a minimum: (1) location of the proposed base station antenna site (latitude and longitude); (2) base station antenna radiation center height above ground level; (3) base station antenna tilt for both mechanical and electrical tilt; and (4) base station antenna specification, including polarization and pattern.
- *Drive-Test Requirements.* Ligado must conduct drive testing to assess actual transmit power levels in the 1526-1536 MHz band to further ensure that its deployed transmit power levels are consistent with the conditions and coordination requirements (e.g., providing coverage maps and monitoring base station transmit power) with GPS device manufacturers. Also, no later than six months following initial base deployments, Ligado must conduct a drive test for each of its deployed areas, and do so for each of its subsequently deployed areas every six months.
- *Public Reporting Mechanism:* Ligado must establish and maintain a toll-free telephone number for the public to report apparent incidences of interference from Ligado's operations to GPS operations.

\* \* \*

Thank you for this opportunity to answer your questions related to the Commission's unanimous, bipartisan decision to continue promoting American leadership in 5G and to protect the important services enabled by GPS. If you would like to discuss this matter further, the FCC stands ready to brief you and your staff on our work.

Sincerely,

A handwritten signature in dark ink, appearing to read "Ajit V. Pai". The signature is fluid and cursive, with the first name "Ajit" being the most prominent part.

Ajit V. Pai



OFFICE OF  
THE CHAIRMAN

FEDERAL COMMUNICATIONS COMMISSION  
WASHINGTON

June 12, 2020

The Honorable Mike Lee  
United States Senate  
361A Russell Senate Office Building  
Washington, DC 20510

Dear Senator Lee:

Thank you for your letter regarding the Commission's unanimous, bipartisan decision to approve with stringent conditions Ligado's application to deploy a low-power terrestrial network in L-band spectrum. I greatly appreciate your support for spectrum policies driven by data and sound engineering as we seek to maintain our nation's leadership in 5G, the next generation of wireless connectivity.

Accordingly, I appreciate the opportunity to answer your questions and clear up some misinformation that has been disseminated regarding the Commission's Ligado decision. Here are my responses to your specific questions.

*How long was the Ligado proceeding on the Commission's docket?*

The Ligado proceeding has been pending for nine years, dating back to the January 2011 authorization to allow Ligado's predecessor-in-interest to commence terrestrial operations if the Commission concluded (after consultation with the Department of Commerce's National Telecommunications and Information Administration) that harmful interference concerns relating to GPS devices had been resolved. (Note: I became a member of the Commission over one year later, in May 2012.)

This proceeding is linked to the Commission's 2003 rulemaking and 2004 authorization to allow terrestrial operations, known as the "ancillary terrestrial component," in this spectrum, which is the 1525-1559 MHz band. This decision was coordinated with the NTIA and used strict emissions limits to create a "quiet zone" to protect from harmful interference GPS operations within the adjacent 1559-1610 band, which is allocated to Radionavigation-Satellite Service (RNSS). In 2005, Commission affirmed its decision to allow terrestrial operations in 1525-1559 MHz band and modified the technical rules to address federal and industry GPS stakeholder concerns.

*Please describe the FCC's evaluation of the Ligado application and why the FCC believes granting this application is in the public interest?*

The Commission has an obligation to review all potential spectrum uses in the public interest. It is a core mission mandated by Congress in law. Recognizing that part of this mission involves promoting American leadership and innovation in 5G, we have created a comprehensive strategy to Facilitate America's Superiority in 5G Technology—the 5G FAST Plan. The plan emphasizes the importance of making more spectrum available for commercial



use. Accordingly, our staff is constantly working to find more ways to maximize efficient use of spectrum for commercial use.

Our decision with respect to the L-band fulfills this goal. Specifically, we found that Ligado's modified application could support 5G and Internet of Things services through an innovative approach to make more efficient use of underused spectrum in the 1525-1536 MHz portion of the mobile satellite band while protecting GPS users in the nearby 1559-1610 MHz radionavigation satellite band.

*The Federal Aviation Administration (FAA) made recommendations to the Commission to protect certified aviation devices from harmful interference. Did the Commission adopt these recommendations?*

Yes, we followed the recommendations of the FAA and the Department of Transportation for certified aviation receivers. See, for example, paragraph 61 of the FCC's Ligado Order ("For certified aviation GPS receivers, we rely on the performance-based standard and analyses conducted by the FAA and presented in the 2018 DOT ABC Report."); see also paragraph 71 ("We accept the FAA's standards-based analyses relating to certified aviation devices and condition Ligado's ATC operations accordingly. The FAA is the expert agency with a critical interest in ensuring the reliability of certified aviation GPS devices.").

*Reports indicate that Ligado entered into co-existence agreements with the major GPS equipment manufacturers. Could you provide a list of which GPS manufacturers that entered into such agreements?*

Since 2015, Ligado has entered into agreements with six different GPS device manufacturers: (1) Garmin International, Inc.; (2) Deere & Company; (3) Trimble Navigation Limited; (4) NovAtel Inc.; (5) Topcon Positioning Systems, Inc.; and (6) Hexagon Positioning Intelligence.

*Roughly what percentage of the GPS market is represented by the manufacturers with these co-existence agreements?*

Based on the record, we expect these manufacturers represent a significant majority of the GPS market. For example, a Brattle Group study indicates that these are the largest manufacturers in four categories of GPS devices—general location/navigation (Garmin), high-precision (Trimble, Deere, Topcon, and Leica), timing (Trimble), and certified aviation (Garmin)—with Garmin alone accounting for nearly half of all consumer general location/navigation device sales in 2015.

*The Commission's order required Ligado to operate its base stations at a 99.3% reduced power level from its original proposal. Why did the Commission conclude that this reduced power level will allow Ligado to operate a terrestrial network that can co-exist with operations in adjacent spectrum bands?*

The power levels were established based on the FAA's analysis relating to protection of certified aviation receivers. To be sure, Ligado's agreements with several GPS device manufacturers indicated that the company's operations even at the higher levels could co-exist with GPS operations. But significantly reducing the permitted power levels goes even further in ensuring that Ligado's lower power operations can co-exist with GPS operations without causing harmful interference.

Furthermore, the Commission also established stringent conditions, including notification requirements, to promote this co-existence. Additional conditions were established specifically to protect U.S. Government users, including the expectation that Ligado and U.S. Government users would negotiate lower power levels (and possible limited exclusion zones), if necessary, to protect sensitive military systems. We also note that the approved power levels also are more than 99% lower than the power levels initially authorized by the Commission for the band in 2004.

*The Commission required Ligado to use a 23 MHz guard band consisting of Ligado's own spectrum. Why does the Commission believe that this guard band will protect from harmful interference?*

The establishment of a 23 megahertz guard band to protect GPS operations effectively extends the quiet zone beyond the 1559-1610 MHz RNSS allocation where GPS satellites operate and into Ligado's own licensed spectrum. That is, Ligado is required effectively to forfeit the use of 23 megahertz of its own spectrum for commercial operations in order to create a buffer between its operations and GPS. (By contrast, the guard band the Commission established in the 600 MHz band between full-power wireless operations and Channel 37 following the broadcast incentive auction was only 3 megahertz, from 614-617 MHz—less than one-seventh as large.) The extended quiet zone is particularly helpful to resolving potential harmful interference to high-precision receivers that are designed to receive signals outside of the RNSS allocation. Testing data in the FCC's record shows that some high-precision receivers operate with mobile satellite service satellites and with GPS satellites simultaneously and others have antennas that, by their design, capture energy outside of the RNSS allocation through use of spectrally inefficient antennas. Colloquially speaking, they "bleed over" into Ligado's spectrum. The guard-band provides an additional quiet zone for these types of high-precision receivers—again, taken out of Ligado's own licensed spectrum.

*Opponents of the FCC's decision have suggested that the guardband is insufficient because GPS receivers are designed to tolerate interference from space systems in adjacent spectrum, but not interference from terrestrial systems in that spectrum. Did the Commission consider and address this concern? If so, how?*

Yes, we considered and addressed this concern. Recall that the Commission, following coordination with NTIA, established rules to permit licensees such as Ligado to operate ancillary terrestrial-based services in 2003, including in the spectrum adjacent to the RNSS allocation. Recall also that in 2004, a predecessor-in-interest to Ligado was authorized to deploy terrestrial operations in that band (the 1525-1559 MHz band) at power levels significantly higher than those we just authorized in the *Ligado Order*. The GPS industry and users knew of the Commission's rulemaking decisions and authorization—and participated in the rulemaking and authorization processes—and the items were appropriately coordinated with NTIA on behalf of federal agencies. In 2005, the Commission affirmed its decision to permit ancillary terrestrial-based operations and addressed all petitions to reconsider the Commission's 2003 decision.

Even though the technical and operational parameters were established and well known by all parties a decade and a half ago, the Commission nonetheless fully examined the data and technical analysis in the record of this recent proceeding. It found that that GPS receivers of all types—including high-precision receivers—are capable of operating effectively with the 23-megahertz guard band inside the 1525-1559 MHz band. In general, the record showed that the

vast majority of GPS receivers would not receive any harmful interference. The Roberson Study found that some of the high-precision receivers, which were most susceptible to interference, were potentially vulnerable, but that repair or replacement of filters would enable the devices to operate without adverse performance impacts. The National Advanced Spectrum and Communications Test Network (NASCTN) report provided support for that same finding. It also found that replacing the antennas of the most vulnerable high-precision devices with a spectrally efficient antenna showed significant susceptibility improvements. Accordingly, the Commission conditioned its approval on Ligado taking responsibility for upgrading or replacing federal agency high-precision receivers, given that interference concerns could be resolved by repairing the receiver or replacing it with receivers with better-performing filters that are designed to operate well primarily within the RNSS allocation (the 1559-1610 MHz band). That is to say, the new receivers are designed to ensure that GPS receivers will not “bleed over” into Ligado’s spectrum. Along with the condition establishing a 23 megahertz guard band, this condition provides significant protection for high-precision receivers using spectrally efficient antennas and enables them to coexist with Ligado’s terrestrial, low-power network.

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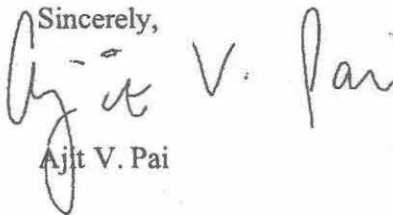
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Thank you for this opportunity to answer your questions related to the Commission's unanimous, bipartisan decision to continue promoting American leadership in 5G and to protect the important services enabled by GPS. If you would like to discuss this matter further, the FCC stands ready to brief you and your staff on our work.

Sincerely,

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Ajit V. Pai



OFFICE OF  
THE CHAIRMAN

FEDERAL COMMUNICATIONS COMMISSION  
WASHINGTON

June 12, 2020

The Honorable Edward J. Markey  
United States Senate  
255 Dirksen Senate Office Building  
Washington, DC 20510

Dear Senator Markey:

Thank you for your letter regarding the Commission's unanimous, bipartisan decision to approve with stringent conditions Ligado's application to deploy a low-power terrestrial network in L-band spectrum. I greatly appreciate your support for spectrum policies driven by data and sound engineering as we seek to maintain our nation's leadership in 5G, the next generation of wireless connectivity.

Accordingly, I appreciate the opportunity to answer your questions and clear up some misinformation that has been disseminated regarding the Commission's Ligado decision. Here are my responses to your specific questions.

*How long was the Ligado proceeding on the Commission's docket?*

The Ligado proceeding has been pending for nine years, dating back to the January 2011 authorization to allow Ligado's predecessor-in-interest to commence terrestrial operations if the Commission concluded (after consultation with the Department of Commerce's National Telecommunications and Information Administration) that harmful interference concerns relating to GPS devices had been resolved. (Note: I became a member of the Commission over one year later, in May 2012.)

This proceeding is linked to the Commission's 2003 rulemaking and 2004 authorization to allow terrestrial operations, known as the "ancillary terrestrial component," in this spectrum, which is the 1525-1559 MHz band. This decision was coordinated with the NTIA and used strict emissions limits to create a "quiet zone" to protect from harmful interference GPS operations within the adjacent 1559-1610 band, which is allocated to Radionavigation-Satellite Service (RNSS). In 2005, Commission affirmed its decision to allow terrestrial operations in 1525-1559 MHz band and modified the technical rules to address federal and industry GPS stakeholder concerns.

*Please describe the FCC's evaluation of the Ligado application and why the FCC believes granting this application is in the public interest?*

The Commission has an obligation to review all potential spectrum uses in the public interest. It is a core mission mandated by Congress in law. Recognizing that part of this mission involves promoting American leadership and innovation in 5G, we have created a comprehensive strategy to Facilitate America's Superiority in 5G Technology—the 5G FAST Plan. The plan emphasizes the importance of making more spectrum available for commercial



use. Accordingly, our staff is constantly working to find more ways to maximize efficient use of spectrum for commercial use.

Our decision with respect to the L-band fulfills this goal. Specifically, we found that Ligado's modified application could support 5G and Internet of Things services through an innovative approach to make more efficient use of underused spectrum in the 1525-1536 MHz portion of the mobile satellite band while protecting GPS users in the nearby 1559-1610 MHz radionavigation satellite band.

*The Federal Aviation Administration (FAA) made recommendations to the Commission to protect certified aviation devices from harmful interference. Did the Commission adopt these recommendations?*

Yes, we followed the recommendations of the FAA and the Department of Transportation for certified aviation receivers. See, for example, paragraph 61 of the FCC's Ligado Order ("For certified aviation GPS receivers, we rely on the performance-based standard and analyses conducted by the FAA and presented in the 2018 DOT ABC Report."); see also paragraph 71 ("We accept the FAA's standards-based analyses relating to certified aviation devices and condition Ligado's ATC operations accordingly. The FAA is the expert agency with a critical interest in ensuring the reliability of certified aviation GPS devices.").

*Reports indicate that Ligado entered into co-existence agreements with the major GPS equipment manufacturers. Could you provide a list of which GPS manufacturers that entered into such agreements?*

Since 2015, Ligado has entered into agreements with six different GPS device manufacturers: (1) Garmin International, Inc.; (2) Deere & Company; (3) Trimble Navigation Limited; (4) NovAtel Inc.; (5) Topcon Positioning Systems, Inc.; and (6) Hexagon Positioning Intelligence.

*Roughly what percentage of the GPS market is represented by the manufacturers with these co-existence agreements?*

Based on the record, we expect these manufacturers represent a significant majority of the GPS market. For example, a Brattle Group study indicates that these are the largest manufacturers in four categories of GPS devices—general location/navigation (Garmin), high-precision (Trimble, Deere, Topcon, and Leica), timing (Trimble), and certified aviation (Garmin)—with Garmin alone accounting for nearly half of all consumer general location/navigation device sales in 2015.

*The Commission's order required Ligado to operate its base stations at a 99.3% reduced power level from its original proposal. Why did the Commission conclude that this reduced power level will allow Ligado to operate a terrestrial network that can co-exist with operations in adjacent spectrum bands?*

The power levels were established based on the FAA's analysis relating to protection of certified aviation receivers. To be sure, Ligado's agreements with several GPS device manufacturers indicated that the company's operations even at the higher levels could co-exist with GPS operations. But significantly reducing the permitted power levels goes even further in ensuring that Ligado's lower power operations can co-exist with GPS operations without causing harmful interference.



Furthermore, the Commission also established stringent conditions, including notification requirements, to promote this co-existence. Additional conditions were established specifically to protect U.S. Government users, including the expectation that Ligado and U.S. Government users would negotiate lower power levels (and possible limited exclusion zones), if necessary, to protect sensitive military systems. We also note that the approved power levels also are more than 99% lower than the power levels initially authorized by the Commission for the band in 2004.

*The Commission required Ligado to use a 23 MHz guard band consisting of Ligado's own spectrum. Why does the Commission believe that this guard band will protect from harmful interference?*

The establishment of a 23 megahertz guard band to protect GPS operations effectively extends the quiet zone beyond the 1559-1610 MHz RNSS allocation where GPS satellites operate and into Ligado's own licensed spectrum. That is, Ligado is required effectively to forfeit the use of 23 megahertz of its own spectrum for commercial operations in order to create a buffer between its operations and GPS. (By contrast, the guard band the Commission established in the 600 MHz band between full-power wireless operations and Channel 37 following the broadcast incentive auction was only 3 megahertz, from 614-617 MHz—less than one-seventh as large.) The extended quiet zone is particularly helpful to resolving potential harmful interference to high-precision receivers that are designed to receive signals outside of the RNSS allocation. Testing data in the FCC's record shows that some high-precision receivers operate with mobile satellite service satellites and with GPS satellites simultaneously and others have antennas that, by their design, capture energy outside of the RNSS allocation through use of spectrally inefficient antennas. Colloquially speaking, they "bleed over" into Ligado's spectrum. The guard-band provides an additional quiet zone for these types of high-precision receivers—again, taken out of Ligado's own licensed spectrum.

*Opponents of the FCC's decision have suggested that the guardband is insufficient because GPS receivers are designed to tolerate interference from space systems in adjacent spectrum, but not interference from terrestrial systems in that spectrum. Did the Commission consider and address this concern? If so, how?*

Yes, we considered and addressed this concern. Recall that the Commission, following coordination with NTIA, established rules to permit licensees such as Ligado to operate ancillary terrestrial-based services in 2003, including in the spectrum adjacent to the RNSS allocation. Recall also that in 2004, a predecessor-in-interest to Ligado was authorized to deploy terrestrial operations in that band (the 1525-1559 MHz band) at power levels significantly higher than those we just authorized in the *Ligado Order*. The GPS industry and users knew of the Commission's rulemaking decisions and authorization—and participated in the rulemaking and authorization processes—and the items were appropriately coordinated with NTIA on behalf of federal agencies. In 2005, the Commission affirmed its decision to permit ancillary terrestrial-based operations and addressed all petitions to reconsider the Commission's 2003 decision.

Even though the technical and operational parameters were established and well known by all parties a decade and a half ago, the Commission nonetheless fully examined the data and technical analysis in the record of this recent proceeding. It found that that GPS receivers of all types—including high-precision receivers—are capable of operating effectively with the 23-megahertz guard band inside the 1525-1559 MHz band. In general, the record showed that the

vast majority of GPS receivers would not receive any harmful interference. The Roberson Study found that some of the high-precision receivers, which were most susceptible to interference, were potentially vulnerable, but that repair or replacement of filters would enable the devices to operate without adverse performance impacts. The National Advanced Spectrum and Communications Test Network (NASCTN) report provided support for that same finding. It also found that replacing the antennas of the most vulnerable high-precision devices with a spectrally efficient antenna showed significant susceptibility improvements. Accordingly, the Commission conditioned its approval on Ligado taking responsibility for upgrading or replacing federal agency high-precision receivers, given that interference concerns could be resolved by repairing the receiver or replacing it with receivers with better-performing filters that are designed to operate well primarily within the RNSS allocation (the 1559-1610 MHz band). That is to say, the new receivers are designed to ensure that GPS receivers will not “bleed over” into Ligado’s spectrum. Along with the condition establishing a 23 megahertz guard band, this condition provides significant protection for high-precision receivers using spectrally efficient antennas and enables them to coexist with Ligado’s terrestrial, low-power network.

*What is the National Advanced Spectrum and Communications Test Network (NASCTN)?*

NASCTN is a multi-agency-chartered partnership that seeks to provide a “neutral forum” for testing, modeling, and analysis necessary to inform spectrum policy and regulations. NASCTN was created in 2015 and is a joint effort involving the National Institute of Standards and Technology, NTIA, DOD, the National Aeronautical and Space Administration, the National Science Foundation, and the National Oceanic and Atmospheric Administration. According to its charter, the organization’s purpose is to “improve opportunities for successful spectrum sharing through accurate, reliable, and unbiased measurements and analyses.”

*During the SASC hearing, critics of the decision suggested that the selection of NASCTN to conduct a study on interference was made by Ligado and therefore produced biased results in favor of Ligado’s position. How does the Commission respond to this assertion?*

There is no evidence that NASCTN produced biased results in favor of Ligado’s position. Indeed, as detailed above, NASCTN includes the participation of certain entities, such as the Department of Defense, which have not been shy about expressing their opposition to the merits of the FCC’s decision. Ligado commissioned NASCTN in April 2016 to study the impact of long-term evolution (LTE) signals in Ligado’s spectrum on GPS devices that operate in the nearby band. The NASCTN tested 14 devices in different categories, including general location/navigation receivers, high-precision (including real-time kinematic) receivers, and GPS-disciplined oscillator (i.e., timing) receivers, and also tested several different antennas—all with resulting details and descriptions designed to facilitate rigorous review and replication of testing of each device under test configured for typical use. The Commission found the data and technical analysis in the NASCTN report to be informative and helpful in assessing the interference concerns at issue.

*Is 1db a standard metric that the Commission has used previously for determinations of harmful interference to adjacent bands?*

No. The Commission has never before applied this metric for determinations of harmful interference to adjacent bands. Similarly, the International Telecommunications Union has not recommended that a 1 dB interference protection criterion be used to set emissions levels to protect against harmful interference in adjacent bands.



*Why was 1db not adopted by the Commission in this instance?*

In paragraph 49 of the *Ligado Order*, the Commission relied on its long-standing definition of “harmful interference”: “[i]nterference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with [international] Radio Regulations.” Notably, this is the same definition used by NTIA and the International Telecommunications Union.

The Commission declined to adopt the 1 dB  $C/N_0$  metric because the record demonstrated that it was poor indicator of harmful interference. *First*, data in the record indicated that a 1 dB  $C/N_0$  degradation does not correlate to any significant error in a GPS device’s reporting of position. In other words, a 1dB  $C/N_0$  degradation does not correlate with harmful interference. *Second*, the model used to apply the metric is not reliable. Studies in the record showed that the variability (error) in reported  $C/N_0$  can be significant, as much as 2-3 dB, due to technical variances in the  $C/N_0$  estimators incorporated in GPS receivers and the algorithms used to calculate  $C/N_0$ . That is, the error in measuring the change in performance can be significantly more than the metric itself that one is trying to apply! For some implementations, the data showed that the  $C/N_0$  estimator provided erroneous  $C/N_0$  estimates more frequently than it provided accurate ones. Indeed, the Commission found that the data “strongly suggest that the  $C/N_0$  estimators are generally not capable of accurate and reliable detection of a 1 dB change in the noise power component of the  $C/N_0$ .” *Finally*, on top of all this, variations in this metric occur even without a signal from Ligado—for example, a GPS receiver may experience a 1 dB or 2 dB degradation through natural occurrences.

In sum, the only reason to use a proxy for harmful interference, like the 1 dB  $C/N_0$  metric, is if it can accurately predict harmful interference more quickly than performance-based testing. That is not the case here. The record amply demonstrated that the 1 dB metric repeatedly failed to accurately predict harmful interference, and on top of that, the Commission had access to actual and credible performance-based testing—testing that it relied upon to ensure there would not be harmful interference.

*If 1db is not the Commission’s standard, how would the use of a 1db standard as proposed by some affect current wireless communications?*

Adoption of such a standard for adjacent band operations could have a profound, negative impact on wireless communications. For example, applying the 1dB  $C/N_0$  metric would have required the Commission to reduce Ligado’s authorized base station power by another 99.99898%, down to 1/1,000 of a watt, less than the power of a Bluetooth device. And applying that metric to Ligado’s authorized power levels would predict harmful interference to GPS receivers on cellphones, despite extensive testing in 2011 (that NTIA acknowledged in 2012) showing no such harmful interference from deployments with 16,073% higher power (1,585 Watts) than the 9.8 Watts approved in the *Ligado Order*.

Applied more broadly, use of this metric would undermine the Commission’s ability to promote efficient use of spectrum and effectively prohibit wireless communications as they stand today in many bands. It would impede, if not implode, the Commission’s ability to reallocate new spectrum to 5G and other next-generation services. It would reduce incentives for incumbents to design spectrally efficient receivers. And from the perspective of millions of

American wireless consumers, this metric would be devastating, forestalling the introduction of advanced wireless services and disincentivizing the development of new wireless devices.

*Did the FCC give other federal agencies notice of the final order prior to its release on April 16, 2020?*

Yes. Federal agencies had actual possession of the draft that the FCC was poised to adopt—and thus an opportunity to comment on it—for almost *half a year* before the FCC finally adopted it.

*If so, which agencies, when where they given notice, and what specific opportunities for input were they afforded prior to the issuance of the final order?*

In October 2019, the FCC sent a draft to NTIA for coordination with the Interdepartment Radio Advisory Committee (IRAC). Led by NTIA, the IRAC's members include the Department of Defense (the Air Force, the Army, the Coast Guard, and the Navy), the Department of Agriculture, the Department of Commerce, the Department of Energy, the Federal Aviation Administration, the Department of Homeland Security, the Department of the Interior, the Department of Justice, the National Aeronautics and Space Administration, the National Science Foundation, the Department of State, the Department of Transportation, the Department of the Treasury, the United States Agency for Global Media, the United States Postal Service, and the Department of Veterans Affairs. In the typical situation, the IRAC process provides for a three-week period for feedback. But in order to give federal agencies more time to formulate comments on the FCC's draft decision, the Commission agreed to extend that three-week period for an additional month.

After receiving input from federal agencies in December 2019, when the Department of Defense informed the Commission that it had additional information to submit for the public record, the FCC paused further work on the application until March so that the Department would have yet another opportunity to share its views with the Commission. Although NTIA did supply additional information from the Department of Defense in April 2020 (a February 2020 Air Force memorandum), it did not supply any additional technical analysis for the Commission's consideration.

*What other dialogue or discussions did you maintain with federal agencies throughout this process?*

In addition to staff discussions, I personally spoke with Secretary of Defense Mark Esper, Under Secretary of Defense for Research and Engineering Michael Griffin, and Deputy Under Secretary of Defense for Research and Engineering Lisa Porter about the matter. I am informed that Commission staff as well were in frequent contact with their counterparts at the Department. In short, federal agencies had every possible opportunity to make their cases to the Commission.

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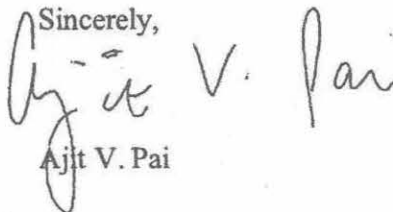
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Thank you for this opportunity to answer your questions related to the Commission's unanimous, bipartisan decision to continue promoting American leadership in 5G and to protect the important services enabled by GPS. If you would like to discuss this matter further, the FCC stands ready to brief you and your staff on our work.

Sincerely,

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Ajit V. Pai



OFFICE OF  
THE CHAIRMAN

FEDERAL COMMUNICATIONS COMMISSION  
WASHINGTON

June 12, 2020

The Honorable Ron Johnson  
United States Senate  
328 Hart Senate Office Building  
Washington, DC 20510

Dear Senator Johnson:

Thank you for your letter regarding the Commission's unanimous, bipartisan decision to approve with stringent conditions Ligado's application to deploy a low-power terrestrial network in L-band spectrum. I greatly appreciate your support for spectrum policies driven by data and sound engineering as we seek to maintain our nation's leadership in 5G, the next generation of wireless connectivity.

Accordingly, I appreciate the opportunity to answer your questions and clear up some misinformation that has been disseminated regarding the Commission's Ligado decision. Here are my responses to your specific questions.

*How long was the Ligado proceeding on the Commission's docket?*

The Ligado proceeding has been pending for nine years, dating back to the January 2011 authorization to allow Ligado's predecessor-in-interest to commence terrestrial operations if the Commission concluded (after consultation with the Department of Commerce's National Telecommunications and Information Administration) that harmful interference concerns relating to GPS devices had been resolved. (Note: I became a member of the Commission over one year later, in May 2012.)

This proceeding is linked to the Commission's 2003 rulemaking and 2004 authorization to allow terrestrial operations, known as the "ancillary terrestrial component," in this spectrum, which is the 1525-1559 MHz band. This decision was coordinated with the NTIA and used strict emissions limits to create a "quiet zone" to protect from harmful interference GPS operations within the adjacent 1559-1610 band, which is allocated to Radionavigation-Satellite Service (RNSS). In 2005, Commission affirmed its decision to allow terrestrial operations in 1525-1559 MHz band and modified the technical rules to address federal and industry GPS stakeholder concerns.

*Please describe the FCC's evaluation of the Ligado application and why the FCC believes granting this application is in the public interest?*

The Commission has an obligation to review all potential spectrum uses in the public interest. It is a core mission mandated by Congress in law. Recognizing that part of this mission involves promoting American leadership and innovation in 5G, we have created a comprehensive strategy to Facilitate America's Superiority in 5G Technology—the 5G FAST Plan. The plan emphasizes the importance of making more spectrum available for commercial



use. Accordingly, our staff is constantly working to find more ways to maximize efficient use of spectrum for commercial use.

Our decision with respect to the L-band fulfills this goal. Specifically, we found that Ligado's modified application could support 5G and Internet of Things services through an innovative approach to make more efficient use of underused spectrum in the 1525-1536 MHz portion of the mobile satellite band while protecting GPS users in the nearby 1559-1610 MHz radionavigation satellite band.

*The Federal Aviation Administration (FAA) made recommendations to the Commission to protect certified aviation devices from harmful interference. Did the Commission adopt these recommendations?*

Yes, we followed the recommendations of the FAA and the Department of Transportation for certified aviation receivers. See, for example, paragraph 61 of the FCC's Ligado Order ("For certified aviation GPS receivers, we rely on the performance-based standard and analyses conducted by the FAA and presented in the 2018 DOT ABC Report."); see also paragraph 71 ("We accept the FAA's standards-based analyses relating to certified aviation devices and condition Ligado's ATC operations accordingly. The FAA is the expert agency with a critical interest in ensuring the reliability of certified aviation GPS devices.").

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Since 2015, Ligado has entered into agreements with six different GPS device manufacturers: (1) Garmin International, Inc.; (2) Deere & Company; (3) Trimble Navigation Limited; (4) NovAtel Inc.; (5) Topcon Positioning Systems, Inc.; and (6) Hexagon Positioning Intelligence.

*Roughly what percentage of the GPS market is represented by the manufacturers with these co-existence agreements?*

Based on the record, we expect these manufacturers represent a significant majority of the GPS market. For example, a Brattle Group study indicates that these are the largest manufacturers in four categories of GPS devices—general location/navigation (Garmin), high-precision (Trimble, Deere, Topcon, and Leica), timing (Trimble), and certified aviation (Garmin)—with Garmin alone accounting for nearly half of all consumer general location/navigation device sales in 2015.

*The Commission's order required Ligado to operate its base stations at a 99.3% reduced power level from its original proposal. Why did the Commission conclude that this reduced power level will allow Ligado to operate a terrestrial network that can co-exist with operations in adjacent spectrum bands?*

The power levels were established based on the FAA's analysis relating to protection of certified aviation receivers. To be sure, Ligado's agreements with several GPS device manufacturers indicated that the company's operations even at the higher levels could co-exist with GPS operations. But significantly reducing the permitted power levels goes even further in ensuring that Ligado's lower power operations can co-exist with GPS operations without causing harmful interference.

Furthermore, the Commission also established stringent conditions, including notification requirements, to promote this co-existence. Additional conditions were established specifically to protect U.S. Government users, including the expectation that Ligado and U.S. Government users would negotiate lower power levels (and possible limited exclusion zones), if necessary, to protect sensitive military systems. We also note that the approved power levels also are more than 99% lower than the power levels initially authorized by the Commission for the band in 2004.

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The establishment of a 23 megahertz guard band to protect GPS operations effectively extends the quiet zone beyond the 1559-1610 MHz RNSS allocation where GPS satellites operate and into Ligado's own licensed spectrum. That is, Ligado is required effectively to forfeit the use of 23 megahertz of its own spectrum for commercial operations in order to create a buffer between its operations and GPS. (By contrast, the guard band the Commission established in the 600 MHz band between full-power wireless operations and Channel 37 following the broadcast incentive auction was only 3 megahertz, from 614-617 MHz—less than one-seventh as large.) The extended quiet zone is particularly helpful to resolving potential harmful interference to high-precision receivers that are designed to receive signals outside of the RNSS allocation. Testing data in the FCC's record shows that some high-precision receivers operate with mobile satellite service satellites and with GPS satellites simultaneously and others have antennas that, by their design, capture energy outside of the RNSS allocation through use of spectrally inefficient antennas. Colloquially speaking, they "bleed over" into Ligado's spectrum. The guard-band provides an additional quiet zone for these types of high-precision receivers—again, taken out of Ligado's own licensed spectrum.

*Opponents of the FCC's decision have suggested that the guardband is insufficient because GPS receivers are designed to tolerate interference from space systems in adjacent spectrum, but not interference from terrestrial systems in that spectrum. Did the Commission consider and address this concern? If so, how?*

Yes, we considered and addressed this concern. Recall that the Commission, following coordination with NTIA, established rules to permit licensees such as Ligado to operate ancillary terrestrial-based services in 2003, including in the spectrum adjacent to the RNSS allocation. Recall also that in 2004, a predecessor-in-interest to Ligado was authorized to deploy terrestrial operations in that band (the 1525-1559 MHz band) at power levels significantly higher than those we just authorized in the *Ligado Order*. The GPS industry and users knew of the Commission's rulemaking decisions and authorization—and participated in the rulemaking and authorization processes—and the items were appropriately coordinated with NTIA on behalf of federal agencies. In 2005, the Commission affirmed its decision to permit ancillary terrestrial-based operations and addressed all petitions to reconsider the Commission's 2003 decision.

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vast majority of GPS receivers would not receive any harmful interference. The Roberson Study found that some of the high-precision receivers, which were most susceptible to interference, were potentially vulnerable, but that repair or replacement of filters would enable the devices to operate without adverse performance impacts. The National Advanced Spectrum and Communications Test Network (NASCTN) report provided support for that same finding. It also found that replacing the antennas of the most vulnerable high-precision devices with a spectrally efficient antenna showed significant susceptibility improvements. Accordingly, the Commission conditioned its approval on Ligado taking responsibility for upgrading or replacing federal agency high-precision receivers, given that interference concerns could be resolved by repairing the receiver or replacing it with receivers with better-performing filters that are designed to operate well primarily within the RNSS allocation (the 1559-1610 MHz band). That is to say, the new receivers are designed to ensure that GPS receivers will not “bleed over” into Ligado’s spectrum. Along with the condition establishing a 23 megahertz guard band, this condition provides significant protection for high-precision receivers using spectrally efficient antennas and enables them to coexist with Ligado’s terrestrial, low-power network.

*What is the National Advanced Spectrum and Communications Test Network (NASCTN)?*

NASCTN is a multi-agency-chartered partnership that seeks to provide a “neutral forum” for testing, modeling, and analysis necessary to inform spectrum policy and regulations. NASCTN was created in 2015 and is a joint effort involving the National Institute of Standards and Technology, NTIA, DOD, the National Aeronautical and Space Administration, the National Science Foundation, and the National Oceanic and Atmospheric Administration. According to its charter, the organization’s purpose is to “improve opportunities for successful spectrum sharing through accurate, reliable, and unbiased measurements and analyses.”

*During the SASC hearing, critics of the decision suggested that the selection of NASCTN to conduct a study on interference was made by Ligado and therefore produced biased results in favor of Ligado’s position. How does the Commission respond to this assertion?*

There is no evidence that NASCTN produced biased results in favor of Ligado’s position. Indeed, as detailed above, NASCTN includes the participation of certain entities, such as the Department of Defense, which have not been shy about expressing their opposition to the merits of the FCC’s decision. Ligado commissioned NASCTN in April 2016 to study the impact of long-term evolution (LTE) signals in Ligado’s spectrum on GPS devices that operate in the nearby band. The NASCTN tested 14 devices in different categories, including general location/navigation receivers, high-precision (including real-time kinematic) receivers, and GPS-disciplined oscillator (i.e., timing) receivers, and also tested several different antennas—all with resulting details and descriptions designed to facilitate rigorous review and replication of testing of each device under test configured for typical use. The Commission found the data and technical analysis in the NASCTN report to be informative and helpful in assessing the interference concerns at issue.

*Is 1db a standard metric that the Commission has used previously for determinations of harmful interference to adjacent bands?*

No. The Commission has never before applied this metric for determinations of harmful interference to adjacent bands. Similarly, the International Telecommunications Union has not recommended that a 1 dB interference protection criterion be used to set emissions levels to protect against harmful interference in adjacent bands.



*Why was 1db not adopted by the Commission in this instance?*

In paragraph 49 of the *Ligado Order*, the Commission relied on its long-standing definition of “harmful interference”: “[i]nterference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with [international] Radio Regulations.” Notably, this is the same definition used by NTIA and the International Telecommunications Union.

The Commission declined to adopt the 1 dB  $C/N_0$  metric because the record demonstrated that it was poor indicator of harmful interference. *First*, data in the record indicated that a 1 dB  $C/N_0$  degradation does not correlate to any significant error in a GPS device’s reporting of position. In other words, a 1dB  $C/N_0$  degradation does not correlate with harmful interference. *Second*, the model used to apply the metric is not reliable. Studies in the record showed that the variability (error) in reported  $C/N_0$  can be significant, as much as 2-3 dB, due to technical variances in the  $C/N_0$  estimators incorporated in GPS receivers and the algorithms used to calculate  $C/N_0$ . That is, the error in measuring the change in performance can be significantly more than the metric itself that one is trying to apply! For some implementations, the data showed that the  $C/N_0$  estimator provided erroneous  $C/N_0$  estimates more frequently than it provided accurate ones. Indeed, the Commission found that the data “strongly suggest that the  $C/N_0$  estimators are generally not capable of accurate and reliable detection of a 1 dB change in the noise power component of the  $C/N_0$ .” *Finally*, on top of all this, variations in this metric occur even without a signal from Ligado—for example, a GPS receiver may experience a 1 dB or 2 dB degradation through natural occurrences.

In sum, the only reason to use a proxy for harmful interference, like the 1 dB  $C/N_0$  metric, is if it can accurately predict harmful interference more quickly than performance-based testing. That is not the case here. The record amply demonstrated that the 1 dB metric repeatedly failed to accurately predict harmful interference, and on top of that, the Commission had access to actual and credible performance-based testing—testing that it relied upon to ensure there would not be harmful interference.

*If 1db is not the Commission’s standard, how would the use of a 1db standard as proposed by some affect current wireless communications?*

Adoption of such a standard for adjacent band operations could have a profound, negative impact on wireless communications. For example, applying the 1dB  $C/N_0$  metric would have required the Commission to reduce Ligado’s authorized base station power by another 99.99898%, down to 1/1,000 of a watt, less than the power of a Bluetooth device. And applying that metric to Ligado’s authorized power levels would predict harmful interference to GPS receivers on cellphones, despite extensive testing in 2011 (that NTIA acknowledged in 2012) showing no such harmful interference from deployments with 16,073% higher power (1,585 Watts) than the 9.8 Watts approved in the *Ligado Order*.

Applied more broadly, use of this metric would undermine the Commission’s ability to promote efficient use of spectrum and effectively prohibit wireless communications as they stand today in many bands. It would impede, if not implode, the Commission’s ability to reallocate new spectrum to 5G and other next-generation services. It would reduce incentives for incumbents to design spectrally efficient receivers. And from the perspective of millions of

American wireless consumers, this metric would be devastating, forestalling the introduction of advanced wireless services and disincentivizing the development of new wireless devices.

*Did the FCC give other federal agencies notice of the final order prior to its release on April 16, 2020?*

Yes. Federal agencies had actual possession of the draft that the FCC was poised to adopt—and thus an opportunity to comment on it—for almost *half a year* before the FCC finally adopted it.

*If so, which agencies, when where they given notice, and what specific opportunities for input were they afforded prior to the issuance of the final order?*

In October 2019, the FCC sent a draft to NTIA for coordination with the Interdepartment Radio Advisory Committee (IRAC). Led by NTIA, the IRAC's members include the Department of Defense (the Air Force, the Army, the Coast Guard, and the Navy), the Department of Agriculture, the Department of Commerce, the Department of Energy, the Federal Aviation Administration, the Department of Homeland Security, the Department of the Interior, the Department of Justice, the National Aeronautics and Space Administration, the National Science Foundation, the Department of State, the Department of Transportation, the Department of the Treasury, the United States Agency for Global Media, the United States Postal Service, and the Department of Veterans Affairs. In the typical situation, the IRAC process provides for a three-week period for feedback. But in order to give federal agencies more time to formulate comments on the FCC's draft decision, the Commission agreed to extend that three-week period for an additional month.

After receiving input from federal agencies in December 2019, when the Department of Defense informed the Commission that it had additional information to submit for the public record, the FCC paused further work on the application until March so that the Department would have yet another opportunity to share its views with the Commission. Although NTIA did supply additional information from the Department of Defense in April 2020 (a February 2020 Air Force memorandum), it did not supply any additional technical analysis for the Commission's consideration.

*What other dialogue or discussions did you maintain with federal agencies throughout this process?*

In addition to staff discussions, I personally spoke with Secretary of Defense Mark Esper, Under Secretary of Defense for Research and Engineering Michael Griffin, and Deputy Under Secretary of Defense for Research and Engineering Lisa Porter about the matter. I am informed that Commission staff as well were in frequent contact with their counterparts at the Department. In short, federal agencies had every possible opportunity to make their cases to the Commission.

*In December 2019, the NTIA sent the FCC a letter that explained it was "unable to recommend the Commission's approval of the Ligado applications." Please describe NTIA's concerns and what steps, if any, the FCC took to address them? Which concerns did the FCC disagree with and why?*

NTIA's December 2019 letter did not itself raise any concerns with the Commission's approval of the Ligado applications, nor did it identify any technical errors in the draft order that the Commission provided to NTIA for the Interdepartment Radio Advisory Committee process. Instead, it lauded the federal government's "tremendous success in making available spectrum



that can support 5G,” argued that GPS is “fundamental to the Nation’s economy, national security, and continued technological leadership,” and noted that “federal agencies have significant concerns,” attaching a December 2018 letter from the National Executive Committee for Space-Based Positioning, Navigation, and Timing (PNT EXCOM), a June 2019 letter from the Department of Defense, and a November 2019 letter from the Department. As detailed in the *Ligado Order*, the Commission appreciated NTIA’s recognition of its work on 5G, agreed on the importance of GPS, and responded to the letters from federal agencies at length.

But neither NTIA’s December 6, 2019 letter, the PNT EXCOM’s December 2018 letter, the Department of Defense’s June 2019 letter, nor the Department of Defense’s November 2019 letter conveyed any new information, data, or arguments not already in the record before the Commission. These submissions simply did not address the substance or technical merits of the approach that the FCC proposed to use to assess the potential for harmful interference to GPS.

Instead, the letters from PNT EXCOM and DOD recommended that any operations in bands adjacent to GPS should not be approved unless, at a minimum, they do not exceed the “tolerable power transmission limits” described in the Department of Transportation’s April 2018 Global Positioning System (GPS) Adjacent Band Compatibility Assessment Final Report. That report, in turn, based its analysis on the flawed 1 dB metric that, as described above, the Commission found to be a poor indicator of harmful interference.

As a result, the Commission did not find these letters persuasive. Instead, following a thorough evaluation of the technical assessments in the record, including those cited by federal agencies in their letters, the Commission concluded that approval of Ligado’s modified applications, with the stringent conditions that we imposed, addressed and resolved the potential harmful interference concerns relating to Ligado’s proposed operations (both generally and specifically with respect to federal users) and would promote the efficient use of spectrum in the public interest.

I would note that in April 2020, NTIA submitted an Air Force memorandum that contained no new technical data for the Commission’s consideration but questioned Ligado’s ability to repair or replace potentially affected legacy equipment. To address this concern, the Commission included additional obligations for Ligado to work with the Department of Defense on mutually agreeable lower power levels over affected military installations and possible exclusion zones.

*The Commission required Ligado to have an “emergency shut off switch” after a notification of credible interference. When would Ligado be required to shut off its network?*

In the *Ligado Order*, the Commission adopted requirements and procedures to ensure the immediate suspension of operations that could potentially cause harmful interference to other services. This “stop buzzer” capability is designed to address an unforeseen disruption to GPS. Ligado must be able to cease transmissions of all base station transmitters within the radio horizon of the impacted area *within 15 minutes* of receiving a request from the FCC’s Operations Center. Any federal agency, Ligado itself, or another source may notify the FCC’s Operations Center of such a GPS disruption.

*Has the Commission previously required an “emergency shut off switch” on spectrum license holders?*



Although this is analogous to a condition the Commission places on experimental licensees, which operate on a non-interference basis relative to other licensees, the Commission has never before required a non-experimental licensee to operate pursuant to this type of requirement. This condition was specifically crafted in the *Ligado Order* to address the concerns of federal users.

*What notification requirements did the Commission place on Ligado prior to base station activations?*

Ligado is subject to several comprehensive conditions designed to help protect GPS users from any potential harmful interference. While some may argue that these conditions go beyond what is necessary given the evidence in the record, I thought that it was important for the Commission to go the extra mile to ensure that military and civilian operations are protected. Specifically, Ligado is subject to the following conditions:

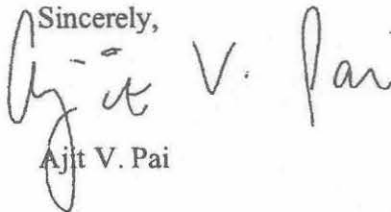
- *Coordination with GPS Device Manufacturers:* Ligado must provide no less than six months' advance notice regarding the activation of any base station transmitting in the 1526-1536 MHz band to Garmin, Deere, Trimble, NovAtel, Topcon, Hexagon, Septentrio, and Leica as well as any other GPS manufacturing company that Ligado knows or reasonably should know could potentially be affected by Ligado's terrestrial network operations.
- *Coordination with Aviation Community:* Ligado must establish a database available to the aviation community and include the base station information at least 30 days before commencing transmission at a base station site. The database must include, at a minimum: (1) location of the proposed base station antenna site (latitude and longitude); (2) base station antenna radiation center height above ground level; (3) base station antenna tilt for both mechanical and electrical tilt; and (4) base station antenna specification, including polarization and pattern. Ligado must also update the database to enter the required base station technical parameters for any subsequently activated base station at least 30 days prior to commencing any transmission.
- *Coordination with Federal GPS Users:* Ligado must launch a program to facilitate the exchange of information between itself and the U.S. Government. Specifically, Ligado must cooperate directly with any U.S. government agency that anticipates that its GPS devices may be affected by Ligado's terrestrial operations by: (1) providing base station location information and technical operating parameters to federal agencies prior to commencing operations in the 1526-1536 MHz band; (2) working with the affected agency to identify the devices that could be affected; (3) working with the affected agency to evaluate whether there would be harmful interference from Ligado's operations; and (4) developing a program for device repair or replacement that is consistent with that agency's programmatic needs, as well as applicable statutes and regulations relating to the ability of those agencies to accept this type of support. Moreover, in the event an affected government agency determines that Ligado's operations will cause harmful interference to a specific, identified GPS receiver operating on a military installation and the receiver is incapable of being fully tested or replaced, Ligado and the affected agency must negotiate an acceptable received-power level over the military installation (which may result in an exclusion zone over the military installation).

- *FCC and FAA Downlink Operations Reports:* At least 30 days before commencing transmission at a base station site, Ligado must submit to the FCC and the FAA a report that includes, at a minimum: (1) location of the proposed base station antenna site (latitude and longitude); (2) base station antenna radiation center height above ground level; (3) base station antenna tilt for both mechanical and electrical tilt; and (4) base station antenna specification, including polarization and pattern.
- *Drive-Test Requirements.* Ligado must conduct drive testing to assess actual transmit power levels in the 1526-1536 MHz band to further ensure that its deployed transmit power levels are consistent with the conditions and coordination requirements (e.g., providing coverage maps and monitoring base station transmit power) with GPS device manufacturers. Also, no later than six months following initial base deployments, Ligado must conduct a drive test for each of its deployed areas, and do so for each of its subsequently deployed areas every six months.
- *Public Reporting Mechanism:* Ligado must establish and maintain a toll-free telephone number for the public to report apparent incidences of interference from Ligado's operations to GPS operations.

\* \* \*

Thank you for this opportunity to answer your questions related to the Commission's unanimous, bipartisan decision to continue promoting American leadership in 5G and to protect the important services enabled by GPS. If you would like to discuss this matter further, the FCC stands ready to brief you and your staff on our work.

Sincerely,

A handwritten signature in dark ink, appearing to read "Ajit V. Pai". The signature is fluid and cursive, with the first name "Ajit" being the most prominent part.

Ajit V. Pai



OFFICE OF  
THE CHAIRMAN

FEDERAL COMMUNICATIONS COMMISSION  
WASHINGTON

June 12, 2020

The Honorable Brian Schatz  
United States Senate  
722 Hart Senate Office Building  
Washington, DC 20510

Dear Senator Schatz:

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*During the SASC hearing, critics of the decision suggested that the selection of NASCTN to conduct a study on interference was made by Ligado and therefore produced biased results in favor of Ligado’s position. How does the Commission respond to this assertion?*

There is no evidence that NASCTN produced biased results in favor of Ligado’s position. Indeed, as detailed above, NASCTN includes the participation of certain entities, such as the Department of Defense, which have not been shy about expressing their opposition to the merits of the FCC’s decision. Ligado commissioned NASCTN in April 2016 to study the impact of long-term evolution (LTE) signals in Ligado’s spectrum on GPS devices that operate in the nearby band. The NASCTN tested 14 devices in different categories, including general location/navigation receivers, high-precision (including real-time kinematic) receivers, and GPS-disciplined oscillator (i.e., timing) receivers, and also tested several different antennas—all with resulting details and descriptions designed to facilitate rigorous review and replication of testing of each device under test configured for typical use. The Commission found the data and technical analysis in the NASCTN report to be informative and helpful in assessing the interference concerns at issue.

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*Why was 1db not adopted by the Commission in this instance?*

In paragraph 49 of the *Ligado Order*, the Commission relied on its long-standing definition of “harmful interference”: “[i]nterference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with [international] Radio Regulations.” Notably, this is the same definition used by NTIA and the International Telecommunications Union.

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In sum, the only reason to use a proxy for harmful interference, like the 1 dB  $C/N_0$  metric, is if it can accurately predict harmful interference more quickly than performance-based testing. That is not the case here. The record amply demonstrated that the 1 dB metric repeatedly failed to accurately predict harmful interference, and on top of that, the Commission had access to actual and credible performance-based testing—testing that it relied upon to ensure there would not be harmful interference.

*If 1db is not the Commission’s standard, how would the use of a 1db standard as proposed by some affect current wireless communications?*

Adoption of such a standard for adjacent band operations could have a profound, negative impact on wireless communications. For example, applying the 1dB  $C/N_0$  metric would have required the Commission to reduce Ligado’s authorized base station power by another 99.99898%, down to 1/1,000 of a watt, less than the power of a Bluetooth device. And applying that metric to Ligado’s authorized power levels would predict harmful interference to GPS receivers on cellphones, despite extensive testing in 2011 (that NTIA acknowledged in 2012) showing no such harmful interference from deployments with 16,073% higher power (1,585 Watts) than the 9.8 Watts approved in the *Ligado Order*.

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But neither NTIA’s December 6, 2019 letter, the PNT EXCOM’s December 2018 letter, the Department of Defense’s June 2019 letter, nor the Department of Defense’s November 2019 letter conveyed any new information, data, or arguments not already in the record before the Commission. These submissions simply did not address the substance or technical merits of the approach that the FCC proposed to use to assess the potential for harmful interference to GPS.

Instead, the letters from PNT EXCOM and DOD recommended that any operations in bands adjacent to GPS should not be approved unless, at a minimum, they do not exceed the “tolerable power transmission limits” described in the Department of Transportation’s April 2018 Global Positioning System (GPS) Adjacent Band Compatibility Assessment Final Report. That report, in turn, based its analysis on the flawed 1 dB metric that, as described above, the Commission found to be a poor indicator of harmful interference.

As a result, the Commission did not find these letters persuasive. Instead, following a thorough evaluation of the technical assessments in the record, including those cited by federal agencies in their letters, the Commission concluded that approval of Ligado’s modified applications, with the stringent conditions that we imposed, addressed and resolved the potential harmful interference concerns relating to Ligado’s proposed operations (both generally and specifically with respect to federal users) and would promote the efficient use of spectrum in the public interest.

I would note that in April 2020, NTIA submitted an Air Force memorandum that contained no new technical data for the Commission’s consideration but questioned Ligado’s ability to repair or replace potentially affected legacy equipment. To address this concern, the Commission included additional obligations for Ligado to work with the Department of Defense on mutually agreeable lower power levels over affected military installations and possible exclusion zones.

*The Commission required Ligado to have an “emergency shut off switch” after a notification of credible interference. When would Ligado be required to shut off its network?*

In the *Ligado Order*, the Commission adopted requirements and procedures to ensure the immediate suspension of operations that could potentially cause harmful interference to other services. This “stop buzzer” capability is designed to address an unforeseen disruption to GPS. Ligado must be able to cease transmissions of all base station transmitters within the radio horizon of the impacted area *within 15 minutes* of receiving a request from the FCC’s Operations Center. Any federal agency, Ligado itself, or another source may notify the FCC’s Operations Center of such a GPS disruption.

*Has the Commission previously required an “emergency shut off switch” on spectrum license holders?*



Although this is analogous to a condition the Commission places on experimental licensees, which operate on a non-interference basis relative to other licensees, the Commission has never before required a non-experimental licensee to operate pursuant to this type of requirement. This condition was specifically crafted in the *Ligado Order* to address the concerns of federal users.

*What notification requirements did the Commission place on Ligado prior to base station activations?*

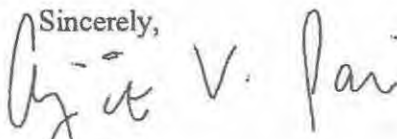
Ligado is subject to several comprehensive conditions designed to help protect GPS users from any potential harmful interference. While some may argue that these conditions go beyond what is necessary given the evidence in the record, I thought that it was important for the Commission to go the extra mile to ensure that military and civilian operations are protected. Specifically, Ligado is subject to the following conditions:

- *Coordination with GPS Device Manufacturers:* Ligado must provide no less than six months' advance notice regarding the activation of any base station transmitting in the 1526-1536 MHz band to Garmin, Deere, Trimble, NovAtel, Topcon, Hexagon, Septentrio, and Leica as well as any other GPS manufacturing company that Ligado knows or reasonably should know could potentially be affected by Ligado's terrestrial network operations.
- *Coordination with Aviation Community:* Ligado must establish a database available to the aviation community and include the base station information at least 30 days before commencing transmission at a base station site. The database must include, at a minimum: (1) location of the proposed base station antenna site (latitude and longitude); (2) base station antenna radiation center height above ground level; (3) base station antenna tilt for both mechanical and electrical tilt; and (4) base station antenna specification, including polarization and pattern. Ligado must also update the database to enter the required base station technical parameters for any subsequently activated base station at least 30 days prior to commencing any transmission.
- *Coordination with Federal GPS Users:* Ligado must launch a program to facilitate the exchange of information between itself and the U.S. Government. Specifically, Ligado must cooperate directly with any U.S. government agency that anticipates that its GPS devices may be affected by Ligado's terrestrial operations by: (1) providing base station location information and technical operating parameters to federal agencies prior to commencing operations in the 1526-1536 MHz band; (2) working with the affected agency to identify the devices that could be affected; (3) working with the affected agency to evaluate whether there would be harmful interference from Ligado's operations; and (4) developing a program for device repair or replacement that is consistent with that agency's programmatic needs, as well as applicable statutes and regulations relating to the ability of those agencies to accept this type of support. Moreover, in the event an affected government agency determines that Ligado's operations will cause harmful interference to a specific, identified GPS receiver operating on a military installation and the receiver is incapable of being fully tested or replaced, Ligado and the affected agency must negotiate an acceptable received-power level over the military installation (which may result in an exclusion zone over the military installation).

- *FCC and FAA Downlink Operations Reports:* At least 30 days before commencing transmission at a base station site, Ligado must submit to the FCC and the FAA a report that includes, at a minimum: (1) location of the proposed base station antenna site (latitude and longitude); (2) base station antenna radiation center height above ground level; (3) base station antenna tilt for both mechanical and electrical tilt; and (4) base station antenna specification, including polarization and pattern.
- *Drive-Test Requirements.* Ligado must conduct drive testing to assess actual transmit power levels in the 1526-1536 MHz band to further ensure that its deployed transmit power levels are consistent with the conditions and coordination requirements (e.g., providing coverage maps and monitoring base station transmit power) with GPS device manufacturers. Also, no later than six months following initial base deployments, Ligado must conduct a drive test for each of its deployed areas, and do so for each of its subsequently deployed areas every six months.
- *Public Reporting Mechanism:* Ligado must establish and maintain a toll-free telephone number for the public to report apparent incidences of interference from Ligado's operations to GPS operations.

\* \* \*

Thank you for this opportunity to answer your questions related to the Commission's unanimous, bipartisan decision to continue promoting American leadership in 5G and to protect the important services enabled by GPS. If you would like to discuss this matter further, the FCC stands ready to brief you and your staff on our work.

Sincerely,  
  
Ajit V. Pai



OFFICE OF  
THE CHAIRMAN

FEDERAL COMMUNICATIONS COMMISSION  
WASHINGTON

June 12, 2020

The Honorable John Thune  
United States Senate  
511 Dirksen Senate Office Building  
Washington, DC 20510

Dear Senator Thune:

Thank you for your letter regarding the Commission's unanimous, bipartisan decision to approve with stringent conditions Ligado's application to deploy a low-power terrestrial network in L-band spectrum. I greatly appreciate your support for spectrum policies driven by data and sound engineering as we seek to maintain our nation's leadership in 5G, the next generation of wireless connectivity.

Accordingly, I appreciate the opportunity to answer your questions and clear up some misinformation that has been disseminated regarding the Commission's Ligado decision. Here are my responses to your specific questions.

*How long was the Ligado proceeding on the Commission's docket?*

The Ligado proceeding has been pending for nine years, dating back to the January 2011 authorization to allow Ligado's predecessor-in-interest to commence terrestrial operations if the Commission concluded (after consultation with the Department of Commerce's National Telecommunications and Information Administration) that harmful interference concerns relating to GPS devices had been resolved. (Note: I became a member of the Commission over one year later, in May 2012.)

This proceeding is linked to the Commission's 2003 rulemaking and 2004 authorization to allow terrestrial operations, known as the "ancillary terrestrial component," in this spectrum, which is the 1525-1559 MHz band. This decision was coordinated with the NTIA and used strict emissions limits to create a "quiet zone" to protect from harmful interference GPS operations within the adjacent 1559-1610 band, which is allocated to Radionavigation-Satellite Service (RNSS). In 2005, Commission affirmed its decision to allow terrestrial operations in 1525-1559 MHz band and modified the technical rules to address federal and industry GPS stakeholder concerns.

*Please describe the FCC's evaluation of the Ligado application and why the FCC believes granting this application is in the public interest?*

The Commission has an obligation to review all potential spectrum uses in the public interest. It is a core mission mandated by Congress in law. Recognizing that part of this mission involves promoting American leadership and innovation in 5G, we have created a comprehensive strategy to Facilitate America's Superiority in 5G Technology—the 5G FAST Plan. The plan emphasizes the importance of making more spectrum available for commercial



use. Accordingly, our staff is constantly working to find more ways to maximize efficient use of spectrum for commercial use.

Our decision with respect to the L-band fulfills this goal. Specifically, we found that Ligado's modified application could support 5G and Internet of Things services through an innovative approach to make more efficient use of underused spectrum in the 1525-1536 MHz portion of the mobile satellite band while protecting GPS users in the nearby 1559-1610 MHz radionavigation satellite band.

*The Federal Aviation Administration (FAA) made recommendations to the Commission to protect certified aviation devices from harmful interference. Did the Commission adopt these recommendations?*

Yes, we followed the recommendations of the FAA and the Department of Transportation for certified aviation receivers. See, for example, paragraph 61 of the FCC's Ligado Order ("For certified aviation GPS receivers, we rely on the performance-based standard and analyses conducted by the FAA and presented in the 2018 DOT ABC Report."); see also paragraph 71 ("We accept the FAA's standards-based analyses relating to certified aviation devices and condition Ligado's ATC operations accordingly. The FAA is the expert agency with a critical interest in ensuring the reliability of certified aviation GPS devices.").

*Reports indicate that Ligado entered into co-existence agreements with the major GPS equipment manufacturers. Could you provide a list of which GPS manufacturers that entered into such agreements?*

Since 2015, Ligado has entered into agreements with six different GPS device manufacturers: (1) Garmin International, Inc.; (2) Deere & Company; (3) Trimble Navigation Limited; (4) NovAtel Inc.; (5) Topcon Positioning Systems, Inc.; and (6) Hexagon Positioning Intelligence.

*Roughly what percentage of the GPS market is represented by the manufacturers with these co-existence agreements?*

Based on the record, we expect these manufacturers represent a significant majority of the GPS market. For example, a Brattle Group study indicates that these are the largest manufacturers in four categories of GPS devices—general location/navigation (Garmin), high-precision (Trimble, Deere, Topcon, and Leica), timing (Trimble), and certified aviation (Garmin)—with Garmin alone accounting for nearly half of all consumer general location/navigation device sales in 2015.

*The Commission's order required Ligado to operate its base stations at a 99.3% reduced power level from its original proposal. Why did the Commission conclude that this reduced power level will allow Ligado to operate a terrestrial network that can co-exist with operations in adjacent spectrum bands?*

The power levels were established based on the FAA's analysis relating to protection of certified aviation receivers. To be sure, Ligado's agreements with several GPS device manufacturers indicated that the company's operations even at the higher levels could co-exist with GPS operations. But significantly reducing the permitted power levels goes even further in ensuring that Ligado's lower power operations can co-exist with GPS operations without causing harmful interference.

Furthermore, the Commission also established stringent conditions, including notification requirements, to promote this co-existence. Additional conditions were established specifically to protect U.S. Government users, including the expectation that Ligado and U.S. Government users would negotiate lower power levels (and possible limited exclusion zones), if necessary, to protect sensitive military systems. We also note that the approved power levels also are more than 99% lower than the power levels initially authorized by the Commission for the band in 2004.

*The Commission required Ligado to use a 23 MHz guard band consisting of Ligado's own spectrum. Why does the Commission believe that this guard band will protect from harmful interference?*

The establishment of a 23 megahertz guard band to protect GPS operations effectively extends the quiet zone beyond the 1559-1610 MHz RNSS allocation where GPS satellites operate and into Ligado's own licensed spectrum. That is, Ligado is required effectively to forfeit the use of 23 megahertz of its own spectrum for commercial operations in order to create a buffer between its operations and GPS. (By contrast, the guard band the Commission established in the 600 MHz band between full-power wireless operations and Channel 37 following the broadcast incentive auction was only 3 megahertz, from 614-617 MHz—less than one-seventh as large.) The extended quiet zone is particularly helpful to resolving potential harmful interference to high-precision receivers that are designed to receive signals outside of the RNSS allocation. Testing data in the FCC's record shows that some high-precision receivers operate with mobile satellite service satellites and with GPS satellites simultaneously and others have antennas that, by their design, capture energy outside of the RNSS allocation through use of spectrally inefficient antennas. Colloquially speaking, they "bleed over" into Ligado's spectrum. The guard-band provides an additional quiet zone for these types of high-precision receivers—again, taken out of Ligado's own licensed spectrum.

*Opponents of the FCC's decision have suggested that the guardband is insufficient because GPS receivers are designed to tolerate interference from space systems in adjacent spectrum, but not interference from terrestrial systems in that spectrum. Did the Commission consider and address this concern? If so, how?*

Yes, we considered and addressed this concern. Recall that the Commission, following coordination with NTIA, established rules to permit licensees such as Ligado to operate ancillary terrestrial-based services in 2003, including in the spectrum adjacent to the RNSS allocation. Recall also that in 2004, a predecessor-in-interest to Ligado was authorized to deploy terrestrial operations in that band (the 1525-1559 MHz band) at power levels significantly higher than those we just authorized in the *Ligado Order*. The GPS industry and users knew of the Commission's rulemaking decisions and authorization—and participated in the rulemaking and authorization processes—and the items were appropriately coordinated with NTIA on behalf of federal agencies. In 2005, the Commission affirmed its decision to permit ancillary terrestrial-based operations and addressed all petitions to reconsider the Commission's 2003 decision.

Even though the technical and operational parameters were established and well known by all parties a decade and a half ago, the Commission nonetheless fully examined the data and technical analysis in the record of this recent proceeding. It found that that GPS receivers of all types—including high-precision receivers—are capable of operating effectively with the 23-megahertz guard band inside the 1525-1559 MHz band. In general, the record showed that the

vast majority of GPS receivers would not receive any harmful interference. The Roberson Study found that some of the high-precision receivers, which were most susceptible to interference, were potentially vulnerable, but that repair or replacement of filters would enable the devices to operate without adverse performance impacts. The National Advanced Spectrum and Communications Test Network (NASCTN) report provided support for that same finding. It also found that replacing the antennas of the most vulnerable high-precision devices with a spectrally efficient antenna showed significant susceptibility improvements. Accordingly, the Commission conditioned its approval on Ligado taking responsibility for upgrading or replacing federal agency high-precision receivers, given that interference concerns could be resolved by repairing the receiver or replacing it with receivers with better-performing filters that are designed to operate well primarily within the RNSS allocation (the 1559-1610 MHz band). That is to say, the new receivers are designed to ensure that GPS receivers will not “bleed over” into Ligado’s spectrum. Along with the condition establishing a 23 megahertz guard band, this condition provides significant protection for high-precision receivers using spectrally efficient antennas and enables them to coexist with Ligado’s terrestrial, low-power network.

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Ligado is subject to several comprehensive conditions designed to help protect GPS users from any potential harmful interference. While some may argue that these conditions go beyond what is necessary given the evidence in the record, I thought that it was important for the Commission to go the extra mile to ensure that military and civilian operations are protected. Specifically, Ligado is subject to the following conditions:

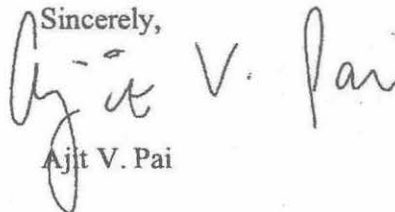
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Thank you for this opportunity to answer your questions related to the Commission's unanimous, bipartisan decision to continue promoting American leadership in 5G and to protect the important services enabled by GPS. If you would like to discuss this matter further, the FCC stands ready to brief you and your staff on our work.

Sincerely,

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Ajit V. Pai



OFFICE OF  
THE CHAIRMAN

FEDERAL COMMUNICATIONS COMMISSION  
WASHINGTON

June 12, 2020

The Honorable Mark Warner  
United States Senate  
703 Hart Senate Office Building  
Washington, DC 20510

Dear Senator Warner:

Thank you for your letter regarding the Commission's unanimous, bipartisan decision to approve with stringent conditions Ligado's application to deploy a low-power terrestrial network in L-band spectrum. I greatly appreciate your support for spectrum policies driven by data and sound engineering as we seek to maintain our nation's leadership in 5G, the next generation of wireless connectivity.

Accordingly, I appreciate the opportunity to answer your questions and clear up some misinformation that has been disseminated regarding the Commission's Ligado decision. Here are my responses to your specific questions.

*How long was the Ligado proceeding on the Commission's docket?*

The Ligado proceeding has been pending for nine years, dating back to the January 2011 authorization to allow Ligado's predecessor-in-interest to commence terrestrial operations if the Commission concluded (after consultation with the Department of Commerce's National Telecommunications and Information Administration) that harmful interference concerns relating to GPS devices had been resolved. (Note: I became a member of the Commission over one year later, in May 2012.)

This proceeding is linked to the Commission's 2003 rulemaking and 2004 authorization to allow terrestrial operations, known as the "ancillary terrestrial component," in this spectrum, which is the 1525-1559 MHz band. This decision was coordinated with the NTIA and used strict emissions limits to create a "quiet zone" to protect from harmful interference GPS operations within the adjacent 1559-1610 band, which is allocated to Radionavigation-Satellite Service (RNSS). In 2005, Commission affirmed its decision to allow terrestrial operations in 1525-1559 MHz band and modified the technical rules to address federal and industry GPS stakeholder concerns.

*Please describe the FCC's evaluation of the Ligado application and why the FCC believes granting this application is in the public interest?*

The Commission has an obligation to review all potential spectrum uses in the public interest. It is a core mission mandated by Congress in law. Recognizing that part of this mission involves promoting American leadership and innovation in 5G, we have created a comprehensive strategy to Facilitate America's Superiority in 5G Technology—the 5G FAST Plan. The plan emphasizes the importance of making more spectrum available for commercial



use. Accordingly, our staff is constantly working to find more ways to maximize efficient use of spectrum for commercial use.

Our decision with respect to the L-band fulfills this goal. Specifically, we found that Ligado's modified application could support 5G and Internet of Things services through an innovative approach to make more efficient use of underused spectrum in the 1525-1536 MHz portion of the mobile satellite band while protecting GPS users in the nearby 1559-1610 MHz radionavigation satellite band.

*The Federal Aviation Administration (FAA) made recommendations to the Commission to protect certified aviation devices from harmful interference. Did the Commission adopt these recommendations?*

Yes, we followed the recommendations of the FAA and the Department of Transportation for certified aviation receivers. See, for example, paragraph 61 of the FCC's Ligado Order ("For certified aviation GPS receivers, we rely on the performance-based standard and analyses conducted by the FAA and presented in the 2018 DOT ABC Report."); see also paragraph 71 ("We accept the FAA's standards-based analyses relating to certified aviation devices and condition Ligado's ATC operations accordingly. The FAA is the expert agency with a critical interest in ensuring the reliability of certified aviation GPS devices.").

*Reports indicate that Ligado entered into co-existence agreements with the major GPS equipment manufacturers. Could you provide a list of which GPS manufacturers that entered into such agreements?*

Since 2015, Ligado has entered into agreements with six different GPS device manufacturers: (1) Garmin International, Inc.; (2) Deere & Company; (3) Trimble Navigation Limited; (4) NovAtel Inc.; (5) Topcon Positioning Systems, Inc.; and (6) Hexagon Positioning Intelligence.

*Roughly what percentage of the GPS market is represented by the manufacturers with these co-existence agreements?*

Based on the record, we expect these manufacturers represent a significant majority of the GPS market. For example, a Brattle Group study indicates that these are the largest manufacturers in four categories of GPS devices—general location/navigation (Garmin), high-precision (Trimble, Deere, Topcon, and Leica), timing (Trimble), and certified aviation (Garmin)—with Garmin alone accounting for nearly half of all consumer general location/navigation device sales in 2015.

*The Commission's order required Ligado to operate its base stations at a 99.3% reduced power level from its original proposal. Why did the Commission conclude that this reduced power level will allow Ligado to operate a terrestrial network that can co-exist with operations in adjacent spectrum bands?*

The power levels were established based on the FAA's analysis relating to protection of certified aviation receivers. To be sure, Ligado's agreements with several GPS device manufacturers indicated that the company's operations even at the higher levels could co-exist with GPS operations. But significantly reducing the permitted power levels goes even further in ensuring that Ligado's lower power operations can co-exist with GPS operations without causing harmful interference.

Furthermore, the Commission also established stringent conditions, including notification requirements, to promote this co-existence. Additional conditions were established specifically to protect U.S. Government users, including the expectation that Ligado and U.S. Government users would negotiate lower power levels (and possible limited exclusion zones), if necessary, to protect sensitive military systems. We also note that the approved power levels also are more than 99% lower than the power levels initially authorized by the Commission for the band in 2004.

*The Commission required Ligado to use a 23 MHz guard band consisting of Ligado's own spectrum. Why does the Commission believe that this guard band will protect from harmful interference?*

The establishment of a 23 megahertz guard band to protect GPS operations effectively extends the quiet zone beyond the 1559-1610 MHz RNSS allocation where GPS satellites operate and into Ligado's own licensed spectrum. That is, Ligado is required effectively to forfeit the use of 23 megahertz of its own spectrum for commercial operations in order to create a buffer between its operations and GPS. (By contrast, the guard band the Commission established in the 600 MHz band between full-power wireless operations and Channel 37 following the broadcast incentive auction was only 3 megahertz, from 614-617 MHz—less than one-seventh as large.) The extended quiet zone is particularly helpful to resolving potential harmful interference to high-precision receivers that are designed to receive signals outside of the RNSS allocation. Testing data in the FCC's record shows that some high-precision receivers operate with mobile satellite service satellites and with GPS satellites simultaneously and others have antennas that, by their design, capture energy outside of the RNSS allocation through use of spectrally inefficient antennas. Colloquially speaking, they "bleed over" into Ligado's spectrum. The guard-band provides an additional quiet zone for these types of high-precision receivers—again, taken out of Ligado's own licensed spectrum.

*Opponents of the FCC's decision have suggested that the guardband is insufficient because GPS receivers are designed to tolerate interference from space systems in adjacent spectrum, but not interference from terrestrial systems in that spectrum. Did the Commission consider and address this concern? If so, how?*

Yes, we considered and addressed this concern. Recall that the Commission, following coordination with NTIA, established rules to permit licensees such as Ligado to operate ancillary terrestrial-based services in 2003, including in the spectrum adjacent to the RNSS allocation. Recall also that in 2004, a predecessor-in-interest to Ligado was authorized to deploy terrestrial operations in that band (the 1525-1559 MHz band) at power levels significantly higher than those we just authorized in the *Ligado Order*. The GPS industry and users knew of the Commission's rulemaking decisions and authorization—and participated in the rulemaking and authorization processes—and the items were appropriately coordinated with NTIA on behalf of federal agencies. In 2005, the Commission affirmed its decision to permit ancillary terrestrial-based operations and addressed all petitions to reconsider the Commission's 2003 decision.

Even though the technical and operational parameters were established and well known by all parties a decade and a half ago, the Commission nonetheless fully examined the data and technical analysis in the record of this recent proceeding. It found that that GPS receivers of all types—including high-precision receivers—are capable of operating effectively with the 23-megahertz guard band inside the 1525-1559 MHz band. In general, the record showed that the

vast majority of GPS receivers would not receive any harmful interference. The Roberson Study found that some of the high-precision receivers, which were most susceptible to interference, were potentially vulnerable, but that repair or replacement of filters would enable the devices to operate without adverse performance impacts. The National Advanced Spectrum and Communications Test Network (NASCTN) report provided support for that same finding. It also found that replacing the antennas of the most vulnerable high-precision devices with a spectrally efficient antenna showed significant susceptibility improvements. Accordingly, the Commission conditioned its approval on Ligado taking responsibility for upgrading or replacing federal agency high-precision receivers, given that interference concerns could be resolved by repairing the receiver or replacing it with receivers with better-performing filters that are designed to operate well primarily within the RNSS allocation (the 1559-1610 MHz band). That is to say, the new receivers are designed to ensure that GPS receivers will not “bleed over” into Ligado’s spectrum. Along with the condition establishing a 23 megahertz guard band, this condition provides significant protection for high-precision receivers using spectrally efficient antennas and enables them to coexist with Ligado’s terrestrial, low-power network.

*What is the National Advanced Spectrum and Communications Test Network (NASCTN)?*

NASCTN is a multi-agency-chartered partnership that seeks to provide a “neutral forum” for testing, modeling, and analysis necessary to inform spectrum policy and regulations. NASCTN was created in 2015 and is a joint effort involving the National Institute of Standards and Technology, NTIA, DOD, the National Aeronautical and Space Administration, the National Science Foundation, and the National Oceanic and Atmospheric Administration. According to its charter, the organization’s purpose is to “improve opportunities for successful spectrum sharing through accurate, reliable, and unbiased measurements and analyses.”

*During the SASC hearing, critics of the decision suggested that the selection of NASCTN to conduct a study on interference was made by Ligado and therefore produced biased results in favor of Ligado’s position. How does the Commission respond to this assertion?*

There is no evidence that NASCTN produced biased results in favor of Ligado’s position. Indeed, as detailed above, NASCTN includes the participation of certain entities, such as the Department of Defense, which have not been shy about expressing their opposition to the merits of the FCC’s decision. Ligado commissioned NASCTN in April 2016 to study the impact of long-term evolution (LTE) signals in Ligado’s spectrum on GPS devices that operate in the nearby band. The NASCTN tested 14 devices in different categories, including general location/navigation receivers, high-precision (including real-time kinematic) receivers, and GPS-disciplined oscillator (i.e., timing) receivers, and also tested several different antennas—all with resulting details and descriptions designed to facilitate rigorous review and replication of testing of each device under test configured for typical use. The Commission found the data and technical analysis in the NASCTN report to be informative and helpful in assessing the interference concerns at issue.

*Is 1db a standard metric that the Commission has used previously for determinations of harmful interference to adjacent bands?*

No. The Commission has never before applied this metric for determinations of harmful interference to adjacent bands. Similarly, the International Telecommunications Union has not recommended that a 1 dB interference protection criterion be used to set emissions levels to protect against harmful interference in adjacent bands.



*Why was 1db not adopted by the Commission in this instance?*

In paragraph 49 of the *Ligado Order*, the Commission relied on its long-standing definition of “harmful interference”: “[i]nterference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with [international] Radio Regulations.” Notably, this is the same definition used by NTIA and the International Telecommunications Union.

The Commission declined to adopt the 1 dB  $C/N_0$  metric because the record demonstrated that it was poor indicator of harmful interference. *First*, data in the record indicated that a 1 dB  $C/N_0$  degradation does not correlate to any significant error in a GPS device’s reporting of position. In other words, a 1dB  $C/N_0$  degradation does not correlate with harmful interference. *Second*, the model used to apply the metric is not reliable. Studies in the record showed that the variability (error) in reported  $C/N_0$  can be significant, as much as 2-3 dB, due to technical variances in the  $C/N_0$  estimators incorporated in GPS receivers and the algorithms used to calculate  $C/N_0$ . That is, the error in measuring the change in performance can be significantly more than the metric itself that one is trying to apply! For some implementations, the data showed that the  $C/N_0$  estimator provided erroneous  $C/N_0$  estimates more frequently than it provided accurate ones. Indeed, the Commission found that the data “strongly suggest that the  $C/N_0$  estimators are generally not capable of accurate and reliable detection of a 1 dB change in the noise power component of the  $C/N_0$ .” *Finally*, on top of all this, variations in this metric occur even without a signal from Ligado—for example, a GPS receiver may experience a 1 dB or 2 dB degradation through natural occurrences.

In sum, the only reason to use a proxy for harmful interference, like the 1 dB  $C/N_0$  metric, is if it can accurately predict harmful interference more quickly than performance-based testing. That is not the case here. The record amply demonstrated that the 1 dB metric repeatedly failed to accurately predict harmful interference, and on top of that, the Commission had access to actual and credible performance-based testing—testing that it relied upon to ensure there would not be harmful interference.

*If 1db is not the Commission’s standard, how would the use of a 1db standard as proposed by some affect current wireless communications?*

Adoption of such a standard for adjacent band operations could have a profound, negative impact on wireless communications. For example, applying the 1dB  $C/N_0$  metric would have required the Commission to reduce Ligado’s authorized base station power by another 99.99898%, down to 1/1,000 of a watt, less than the power of a Bluetooth device. And applying that metric to Ligado’s authorized power levels would predict harmful interference to GPS receivers on cellphones, despite extensive testing in 2011 (that NTIA acknowledged in 2012) showing no such harmful interference from deployments with 16,073% higher power (1,585 Watts) than the 9.8 Watts approved in the *Ligado Order*.

Applied more broadly, use of this metric would undermine the Commission’s ability to promote efficient use of spectrum and effectively prohibit wireless communications as they stand today in many bands. It would impede, if not implode, the Commission’s ability to reallocate new spectrum to 5G and other next-generation services. It would reduce incentives for incumbents to design spectrally efficient receivers. And from the perspective of millions of

American wireless consumers, this metric would be devastating, forestalling the introduction of advanced wireless services and disincentivizing the development of new wireless devices.

*Did the FCC give other federal agencies notice of the final order prior to its release on April 16, 2020?*

Yes. Federal agencies had actual possession of the draft that the FCC was poised to adopt—and thus an opportunity to comment on it—for almost *half a year* before the FCC finally adopted it.

*If so, which agencies, when where they given notice, and what specific opportunities for input were they afforded prior to the issuance of the final order?*

In October 2019, the FCC sent a draft to NTIA for coordination with the Interdepartment Radio Advisory Committee (IRAC). Led by NTIA, the IRAC's members include the Department of Defense (the Air Force, the Army, the Coast Guard, and the Navy), the Department of Agriculture, the Department of Commerce, the Department of Energy, the Federal Aviation Administration, the Department of Homeland Security, the Department of the Interior, the Department of Justice, the National Aeronautics and Space Administration, the National Science Foundation, the Department of State, the Department of Transportation, the Department of the Treasury, the United States Agency for Global Media, the United States Postal Service, and the Department of Veterans Affairs. In the typical situation, the IRAC process provides for a three-week period for feedback. But in order to give federal agencies more time to formulate comments on the FCC's draft decision, the Commission agreed to extend that three-week period for an additional month.

After receiving input from federal agencies in December 2019, when the Department of Defense informed the Commission that it had additional information to submit for the public record, the FCC paused further work on the application until March so that the Department would have yet another opportunity to share its views with the Commission. Although NTIA did supply additional information from the Department of Defense in April 2020 (a February 2020 Air Force memorandum), it did not supply any additional technical analysis for the Commission's consideration.

*What other dialogue or discussions did you maintain with federal agencies throughout this process?*

In addition to staff discussions, I personally spoke with Secretary of Defense Mark Esper, Under Secretary of Defense for Research and Engineering Michael Griffin, and Deputy Under Secretary of Defense for Research and Engineering Lisa Porter about the matter. I am informed that Commission staff as well were in frequent contact with their counterparts at the Department. In short, federal agencies had every possible opportunity to make their cases to the Commission.

*In December 2019, the NTIA sent the FCC a letter that explained it was "unable to recommend the Commission's approval of the Ligado applications." Please describe NTIA's concerns and what steps, if any, the FCC took to address them? Which concerns did the FCC disagree with and why?*

NTIA's December 2019 letter did not itself raise any concerns with the Commission's approval of the Ligado applications, nor did it identify any technical errors in the draft order that the Commission provided to NTIA for the Interdepartment Radio Advisory Committee process. Instead, it lauded the federal government's "tremendous success in making available spectrum

that can support 5G,” argued that GPS is “fundamental to the Nation’s economy, national security, and continued technological leadership,” and noted that “federal agencies have significant concerns,” attaching a December 2018 letter from the National Executive Committee for Space-Based Positioning, Navigation, and Timing (PNT EXCOM), a June 2019 letter from the Department of Defense, and a November 2019 letter from the Department. As detailed in the *Ligado Order*, the Commission appreciated NTIA’s recognition of its work on 5G, agreed on the importance of GPS, and responded to the letters from federal agencies at length.

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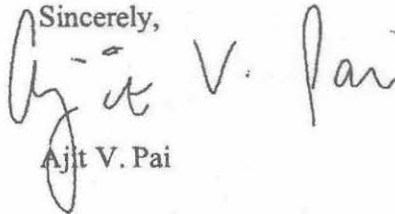
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